Rural Primary School Students' Experiences of a University Science Outreach Programme: Explorations of a Cultural Fit between Students' Culture and the Chemistry Outreach Programme

Gloria Penrice

A thesis
submitted in partial fulfillment of the requirements
for the Degree of Doctor of Philosophy

College of Education
University of Otago
2016

ABSTRACT

There are widespread concerns internationally (Logan & Skamp. 2013; Martin, Mullis, Foy & Stanco, 2012) and in New Zealand (Chamberlain & Caygill, 2013; Gluckman, 2011; Ministry of Business, Innovation and Employment, 2014) about the decline in students' interest and engagement in science education. As a result, fewer students are choosing to study science in the later secondary school years and to pursue science careers. This has lead to a decreasing number of science graduates, potentially negatively impacting on nations' economic competitiveness and productivity. Furthermore, there are fewer scientifically literate citizens who are able to participate in science orientated discussions, debates and developments in society.

This study explored rural primary school students' experiences of Chemistry Outreach, a year-long science programme, which culminated in the students planning, designing, conducting and evaluating scientific investigations in their community. Previous research in science education has focused predominantly on single-level classes within urban and larger rural schools whereas this study's focus was exclusively on a multi-level class in a very small New Zealand rural primary school.

This phenomenological study investigated nine Year 4 – 6 students' experiences of Chemistry Outreach with a specific focus on students' attitudes, engagement, use of scientific skills, and scientific language. Focus group interviews, videos, reflective writing and science book covers were analysed from the individual and social perspective using phenomenology and discourse analysis. The findings were examined in relation to the specific rural culture of these participants through the culturally responsive pedagogy outlined in *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011).

The results revealed the individual journeys the students took, and in the process, exposed the multifaceted influences on their attitudes, engagement and thinking in science. The study highlights the importance of making science useful, relevant and meaningful for these rural students by incorporating their rural culture into the teaching and learning programme.

ACKNOWLEDGEMENTS

Undertaking a doctoral dissertation is not a solo effort and I would like to take this opportunity to acknowledge the help and support I have received over the past four years.

I am especially indebted to my supervisor, Dr Steven Sexton, who has provided professional advice, guidance and direction. His prompt responses to my queries and feedback on my writing has helped to ease the demands and isolation I experienced being a full-time at-distance student as well as a full-time teaching school principal of a very small school. I very much appreciate his in-depth knowledge of the area of primary school science. I would also like to acknowledge the ongoing support and interest provided by Professor Jeff Smith, in particular his insightful feedback on my writing.

This study would not have been possible without the willing participation of the rural school students, their parents, and the rural community members. Thank you so much for speaking so openly and honestly about your experiences.

I would like to acknowledge Dr Dave Warren. Your enthusiasm, friendliness, sense of fun, and unfailing commitment to the Chemistry Outreach programme really brought science alive for the students. A very special thanks to the university students who visited as part of the Chemistry Outreach team, in particular, Dan and Jeff, and Trudy Geoghegan and her team, Cleo Davie- Martin and Katy Orr who worked with the students on their community investigations. You are all inspirational role models.

To my present school, Taieri Beach School, a heartfelt thank you for allowing me to accept my 7 months study leave in 2015 to complete the writing of this study.

I would like to thank the Remote Services Library Staff at the University of Otago for their bibliographic expertise in tracking down all the references I requested and forwarding them to me so quickly.

To my special mother-in-law for her unfailing interest and words of encouragement, thank you so much.

Most importantly, I would like to thank my loving and understanding husband for his patience, encouragement, and unconditional support. You have been my pillar of strength and support over the years and you never gave up believing in me. Without you this thesis would not have been started, let alone finished. Thank you so much for giving me the time and space to follow my hopes and dreams. I love you dearly.

Table of Contents

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE
INTRODUCTION

1.0 Introduction

This phenomenological study explores rural primary school students' experiences of science education. Unlike most earlier research studies in science education which focused predominantly on single-level classes within urban and larger rural schools, here the focus is exclusively on a multi-level class in a very small rural primary school. The data include focus group interviews and video recordings of nine Year 4 - 6 students engaged in scientific activities, as part of a year-long Chemistry Outreach science programme. The results will be discussed in relation to the school's unique culture and the cultural responsive pedagogy outlined in *Tātaiako*: *Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011).

To situate this study with regard to existing research literature, I give a brief overview of the broad picture of science and science education in the twenty-first century, and then explore the research literature regarding science education from an international and New Zealand perspective. I then proceed to describe the research school's context, establishing in the process why it is classified as a very small rural primary school, and explain the Chemistry Outreach programme. I then discuss the present research study. Finally, I conclude this chapter with an outline of the thesis.

1.1 Science in the twenty-first century

Science helps us make sense of the world we live in, discover how things work, seek possible ways for improvement, and transform our environment. It is fundamental to the understanding of the many challenges and concerns of the twenty-first century that confront New Zealand and the world as a whole (Gluckman, 2011). Global issues, including aspects of climate change and genetic modification, as well as local issues, like environmental sustainability, can be considered from a scientific perspective in addition to social and ethical considerations (Ministry of Education, 2007). It follows that informed discussion of these issues can occur as a result of a sound knowledge and understanding of the pertinent scientific concepts and processes.

Clearly, science is important for those who are planning to pursue an applied science career, such as scientific research and development. There is a strong correlation between a country's economic well-being and the numbers of science professionals such as engineers and scientists (Eilks, Nielsen & Hofstein, 2013). Scientific advances are important drivers of economic performance (Organisation for Economic Cooperation and Development, 2000). Furthermore, there are varying degrees of scientific knowledge and understanding required in many of the employment opportunities of the twenty-first century including medicine, manufacturing, engineering, building, farming, and fishing. Therefore, scientific competence and innovation is vital for a nation's economic future (Cowie, Jones & Otrel-Cass, 2011; Tytler, Osborne, Williams, Tytler & Cripps Clark, 2008).

In summary, science is important for understanding the world we live in, developing problem solving skills and informing decision-making in response to the challenges of the modern world, underpinning many of the employment opportunities of the twenty-first century, and boosting a nation's economic prosperity. Hence, science is not only for those intending to pursue science related professions, but also is an essential core knowledge that enables individuals to function effectively as "critical, informed, and responsible citizens in a society in which science plays a significant role" (Ministry of Education, 2007, p. 17). It follows that a strong, future-focused science education is paramount to every nation's economic performance and social well-being.

1.1.1 Science education for the twenty-first century

Science has changed over the years, moving away from a field of knowledge that deals with absolutes through scientific procedures that produce outcomes with "certainity and exactitude" (Gluckman, 2011, p. 3). Present day science is a continually changing and developing field (Peacock, 2007) with scientific information and understandings “constantly re-evaluated in the light of new evidence” (Ministry of Education, 2007, p. 28), and in response to societal demands for improvement. The work of scientists has also evolved from an individualistic undertaking to a more collaborative, team orientated approach with connections with other scientists, researchers, and society through industry, economists and politicians (Peacock, 2007). Science education needs to acknowledge these considerations.

The purpose of science education in the twenty-first century is not solely to produce the next generation of scientists. This traditional pre-professional education focuses on the skills and knowledge required for a science career and is driven by the supply of a skilled workforce to meet the demands of industrial requirements as well as economic and technological growth (Bull et al., 2010). Of equal importance are the citizen-focused purposes of science education which involve cultural and intrinsic values for individuals and society in general (Osborne & Hennessy, 2003; Tytler et al., 2008). The citizen-focused approach to science education incorporates utiliarian, democractic/citizenship and cultural/intellectual aspects. The utilitarian aspect includes the basic knowledge of how things work in the world, that is the natural world, the human body, everyday tools, machines, and technology in order to assist in making more relevant or appropriate decisions for everyday living. The democratic/citizenship purpose in science education relates to the building of scientific literacy and the knowledge of how the scientific process functions in order to ensure the informed participation in science related debates, issues, and policy decisions that face citizens in the twenty first century. The cultural/intellectual purpose in science education involves developing a knowledge of science and scientific thinking in order to critically evaluate the reliability of the ever increasing amount of knowledge that is available in this information-rich world (Bull et al., 2010; Gluckman, 2011).

1.1.2 Science curriculum

Taking into account the pre-professional education and citizen-focused purposes of science education, it follows that a school science curriculum in the twenty-first century should focus on all students developing an interest in science and engaging with science learning within a context-led programme (Tytler, 2007). The following examines the official New Zealand school science curriculum in light of these observations.

The New Zealand Curriculum (Ministry of Education, 2007) is the most recent official national curriculum document. It is not intended to be a prescriptive, detailed plan of knowledge to be taught, but rather a framework for teaching which gives schools "the scope, flexibility and authority they need to design and shape their curriculum so that teaching and learning is meaningful and beneficial to their particular communities of students" (Ministry of Education, 2007, p. 37). The essence statement for the science learning area states " students explore how both the natural physical world and science itself work so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role" (Ministry of Education, 2007, p. 17). The science learning area has an "overarching unifying strand", the Nature of Science, which develops the students' awareness of "what science is and how scientists work" (Ministry of Education, 2007, p. 28). The other strands, Living World (biology, botany, zoology), Planet Earth and Beyond (astronomy and geology), Material World (chemistry) and the Physical World (physics), provide the context through which students learn about science and how it works. This curriculum has an emphasis on equipping all students with the scientific knowledge, skills, and understandings to be successful, informed citizens in the twenty-first century (Ministry of Education, 2007). Therefore, the intent of *The New Zealand Currriculum* (Ministry of Education, 2007) is for school science education programmes to contain the pre-professional education and citizen-focused objectives of science education (Bull et al., 2010).

A science curriculum that encourages all students to engage with, and achieve in science can be viewed as "a social justice and equity matter because of the role science and its technological applications play in defining many of the key issues and opportunities facing society today" (Cowie, et al., 2011, p. 347) and in the future. Therefore, it is vital all students have the opportunity to participate and achieve within the school science curriculum at primary and secondary level.

1.1.3 Science education: an international perspective

There are widespread concerns internationally about the decline in students' interest and engagement with science (Fensham, 2007; Osborne, Simon & Collins, 2003; Tytler et al., 2008). An increasing disillusionment with science among the later primary school and secondary school students has been reported in many countries including England (Osborne & Collins, 2001), Ireland **(**Varley, Murphy & Veale, 2008), the Netherlands (Eijkelhof & Voogt, 2001)**,** Sweden, (Lindahl, 2003), Canada **(**Bordt, De Broucker, Read, Harris & Zhang, 2001), Japan **(**Goto, 2001), and Australia (Lyons, 2003). As a result, there is a decreasing number of high quality science graduates which has the potential to negatively impact on a nation's future economic competitiveness and productivity. Furthermore, there are less scientifically literate citizens who are able to participate in science orientated discussions, debates, and developments in society.

Many students report negative experiences of science, especially in the later primary and secondary school level. They often see science as uninspiring, lacking relevance and significance to their everyday lives; complex and challenging to learn; and involving a transmissive pedagogy which does not give them an opportunity to investigate their own questions as evidenced in studies from Sweden (Lindahl, 2003), England (Osborne & Collins, 2001), Ireland (Varley et al., 2008), and Australia (Lyons, 2006). There is a strong correlation between negative experiences of school science and the reluctance to pursue further science study once it is no longer a compulsory subject within the school curriculum (Lindahl, 2003).

Of great concern are the reports of students who are high achievers in science, and were initally keen to pursue a science career but were dissuaded by their less than positive school science experiences as evidenced in studies from Australia (Lyons, 2003), Canada

(Bordt et al., 2001), and Japan (Goto, 2001). Consequently, negative experiences of school science are resulting in fewer students choosing to study science in the later secondary school years culminating in a decline in student interest in pursuing a science career (Organisation for Economic Cooperation and Development, 2007).

Factors including lack of teacher confidence and ability to teach science, accountability demands, pressures of time, and overcrowded curriculums have been identified as contributing to students' negative experiences of science (Goodrum, Hackling & Rennie, 2001; Murphy, Neil & Beggs, 2007; Tytler et al., 2008). Many teachers lack confidence in teaching primary school science, and often avoid or let science lessons slide if other interruptions occur during the day (Goodrum et al., 2001). To illustrate, half of the teachers in a survey in England reported science as the subject they were least confident teaching (Murphy et al., 2007). When teachers lack confidence in teaching science, they are more inclined to revert to a transmissive style of pedagogy, focus on the knowledge component of science, and give less time to encouraging student-led hands-on investigative work to develop genuine scientific inquiry skills (Tytler et al., 2008; Varley et al., 2008).

Accountability demands place a strong emphasis on literacy and mathematics in the primary school years with expected benchmarks or standards to achieve at certain ages, and/or policies such as the American 'No Child Left Behind' (Cleary, 2004). This exerts pressures on teachers to have students achieve in English and Mathematics, so teachers concentrate their teaching and professional development in these areas of the curriculum. Accountability demands, an already overcrowded primary school curriculum, teachers who lack confidence in the teaching science and the lack of professional development opportunities all contribute to a less than positive science experience for many science students (Lyons, 2006, Tytler et al., 2008).

1.1.4 Science education: New Zealand perspective

Concerns about the diminishing interest in science and science careers are also echoed in the New Zealand research literature. Similar to international research findings, there is less interest by New Zealand students to specialise in science at secondary school and tertiary level, and to consider science as a career option (Bolstad & Hipkins, 2008; Bull et al., 2010; Hipkins, Roberts, Bolstad & Ferral, 2006). It is disturbing to note that the results from New Zealand's National Education Monitoring Project (NEMP) from 1995 to 2007 and the 2012 National Monitoring Study of Student Achievement (NMSSA) indicate a strong pattern of decline in engagement in science from Year 4 to Year 8 (Crooks & Flockton, 1996, 2000, 2004; Crooks, Smith, & Flockton, 2008; Ministry of Education, 2013b), somewhat earlier than the age of 14 indicated in Australian studies (Tytler et al., 2008). Although the NEMP and NMSSA results show Year 4 students to be relatively positive about science compared to the Year 8 students (Crooks & Flockton, 1996, 2000, 2004; Crooks et al., 2008; Ministry of Education, 2013b), Trends in International Mathematics and Science Study (TIMSS) 2010/11 results indicate that by Year 5, students were somewhat neutral in their views about science, and displayed less confidence and engagement with school science relative to international findings (Chamberlain & Caygill, 2013; Martin, Mullis, Foy & Stanco, 2012).

Although New Zealand does have a high rate of top achievers in science compared to many other countries, there is also a long tail of underachievers who show little interest and ability in science (Bull et al., 2010; Gluckman, 2011). TIMSS 2010/11 results show New Zealand Year 5 students had an appreciably lower science achievement rate compared to England, United States, and Australia (Chamberlain & Caygill, 2013). Students have good observational skills but there is a pattern over the years of students having difficulty explaining scientific ideas and understandings because of their lack of scientific skills and scientific language (Crooks & Flockton, 1996, 2000, 2004; Crooks et al., 2008). This pattern continued into the secondary school area with New Zealand's 15 years old students in the 2006 Programme for International Student Assessment (PISA) showing more strengths in using scientific evidence than explaining scientific concepts (Bull et al., 2010; Caygill, 2008).

Factors that influence students' interest in science and ability in science include the constraints of time, programme organisation, the generalist classroom teacher, accountability demands, and teacher professional development (Chamberlain & Caygill, 2012; Education Review Office, 2012; Gluckman, 2011). The following discusses these factors within the New Zealand primary school context.

The amount of time teachers spent teaching science was regularly surveyed as part of the TIMSS project. If science was not taught as a stand alone subject, teachers were asked to estimate the amount of science instruction within the integrated programme. The results for New Zealand Year 5 students showed a significant drop from an average of 66 hours a year in 2002, down to 45 hours in 2006/2007, with a slight increase in 2010/2011 to an average of 52 hours a year. Comparisons with other countries show that in 2006/7, the average time spent per year on Year 5 science in New Zealand was 45 hours, comparable to Australia's 46 hours, but well behind England's 70 hours and America's 89 hours per year. Only 4 years later, in 2010/2011, New Zealand had slipped significantly relative to other countries with an average of 52 hours instruction, compared to the increase in hours for Australia (from 46 to 65 hours), England (from 70 to 76 hours) and America (from 89 to 105 hours). These results indicate New Zealand schools spend fewer instructional hours in science than most other English speaking countries (Caygill, 2008; Chamberlain & Caygill, 2012). Although the parameters of the TIMSS project did not include any indications of quality of instruction, less time spent on science teaching and learning culminates in fewer opportunities for students to engage in hands-on, student-directed scientific investigations (Ministry of Education, 2009a). This is reflected in the 1999-2007 NEMP results and 2012 NMSSA results where Year 4 and 8 students reported a decreasing likelihood of doing really good things in science at school, and less opportunities to learn about science at school despite the majority of these students indicating that they would like more science experiences at school (Ministry of Education, 2013b). Furthermore, time constraints limited the opportunities for students to engage in hands-on science activities with over two thirds of Year 4 students stating they very rarely did experiments with everyday things or science equipment (Crooks & Flockton, 2000, 2004; Crooks et al., 2008; Ministry of Education, 2013b).

The programme organisation in many schools can be influenced by an overcrowded curriculum (Garbett, 2011). Schools often use a topic approach where science is covered either as a stand alone subject once or twice a year, or within an integrated inquiry topic approach. This can result in science being taught only once or twice a year thereby preventing the cyclical nature of science education required to consolidate students' conceptual knowledge and scientific skills (Bull et al., 2010; Gluckman, 2011).

In New Zealand primary schools, science is generally taught by a generalist classroom teacher as opposed to a specialist science teacher. As a result, the quality of teaching can vary as most primary teachers are trained in the humanities and often lack the confidence, specialised knowledge, and supporting professional development to offer intellectually demanding science learning experiences to their students (Bull et al., 2010; Caygill, 2008; Cooper, Cowie & Jones, 2011; Education Review Office, 2012; Garbett, 2011; Gluckman, 2011; Ministry of Education, 2013b). *The New Zealand Curriculum* (Ministry of Education, 2007) stresses the importance of situating teaching of science within "contexts relevant to local needs and students" (Cowie et al., 2011, p. 352). This requires teachers to have the knowledge and skills to recognise possible opportunities for science teaching within the local environment and to employ effective pedagogy to promote student learning through this context (Cooper et al., 2011; Garbett, 2011).

The assessment-driven accountability demands in New Zealand primary schools evidenced in policy agendas such as the National Standards in Literacy and Mathematics (Ministry of Education, 2009c, 2009d) have also impacted on the amount of science teaching within classroom programmes. From 2010, all New Zealand primary schools are required to report reading, writing, and mathematics attainments in relation to the National Standards to their communities and to the Ministry of Education. It is significant that Student Achievement Targets which form part of each school's Annual Plan generally contain either a literacy and/or mathematics focus, no doubt as a result of the government's emphasis on the assessment of these curriculum areas through the introduction of the National Standards. As a consequence, primary school teachers do not rank science as highly as literacy and numeracy within their everyday programme (Cooper et al., 2011) and accordingly devote more instructional time to the basic curriculum areas of reading, writing, and mathematics.

The accountability demands in English and Mathematics within the New Zealand primary education system have resulted in teachers focusing their professional development in these areas. Although many teachers may feel inadequate in the teaching of science in the primary school due to their limited scientific knowledge base and skills, they are more likely to engage in literacy and mathematics than science professional development (Cooper et al., 2011). In a study examining the quality of Year 4 and 8 science teaching in 100 schools, 73% of school had not received science professional development. In contrast, it was found that effective schools had participated in science professional development (Education Review Office, 2012). These findings add to a previous study examining the quality of Year 4 and 8 science teaching in 233 schools, 56% of science teachers indicated they had not had any science professional development in the past year (Education Review Office, 2004). However, it was found that effective science teachers had participated in recent science professional development (Education Review Office, 2004). Very few schools identify science as a schoolwide professional development focus, as evidenced in a study of 196 primary school principals by Schagen and Hipkins (2008) where only two percent of principals prioritised science as a curriculum focus in their schools. This needs to be considered in relation to the fact that many schools were involved in professional development in implementing the draft New Zealand Curriculum which was to be mandated in 2010. Futhermore, there was an abundance of professional development available for various forms of inquiry learning, as well as a push to incorporate the use of ICT in scholwide programmes, and an emphasis of Ministry of Education funded professional development on mathematics, reading, and writing (Schagen & Hipkins, 2008).

In summary, many of the international concerns regarding students' diminishing interest and achievement in school science are found within the New Zealand context. Studies have shown that there is less instructional time spent on science in New Zealand classrooms compared to many other international countries. This means less opportunity for students to experience the development of scientific inquiry skills through student-led hands-on practical investigations. The way many schools organise their science programme results in the lack of opportunity to revisit science concepts throughout the year. Schools often focus on the Mathematics and English curriculum areas due to accountability demands. Furthermore, there is less teacher professional development available in science compared to Mathematics and English. Overall, the teaching of science does not seem to rank very high in the New Zealand curriculum programme. Consequently, many primary school children are increasingly developing a negative attitude towards science.

In my opinion, a review of the situation of New Zealand science education is not complete without considering science education within the rural context. The following explains this in more detail.

1.1.5 Science education in New Zealand rural schools

There is a paucity of research specifically focused on the New Zealand rural education scene (Wright, 2012). Despite a third of New Zealand schools being classified as rural schools (Education Review Office, 2015), there has been no research pertaining to rural schools published in the leading New Zealand educational research journal, the *New Zealand Journal of Educational Studies (NZJES),* between 2006 and 2012 (Carpenter & Dunn, 2012). This gap in *NZJES* was addressed in part by my own research (see Penrice, 2012) on accountability issues facing rural primary teachers, which built on earlier research (Penrice, 2011) on the intensification of rural teachers' work. Although both these studies were situated within the rural context, only one of the participant teachers came from a small rural school, and none came from very small schools.

To explain this classification of schools further, New Zealand primary schools with rolls of 180 students or less are classified as small schools. In these schools principals have a teaching component, which increases as the school roll decreases. In one and two-teacher schools, which have rolls of less than 50 students, the teaching component is 0.7, which equates to three and half days teaching a week. Half of the total 2045 primary schools in New Zealand have rolls less than 180 students and therefore are categorized as small schools. Furthermore, 20% of these schools have rolls less than 50 students, and are described as very small schools. Of these very small schools, 98% are classified as rural (Statistics New Zealand, 2004). The Education Review Office (2015) regards very small schools as 30 or less pupils. This study also takes the stance that very small schools have rolls of less than 30 students, as these school generally have one or two teachers compared to schools with less than 50 which can have up to three or four teachers.

Research in science education has focused predominantly on single-level classes within urban and larger rural schools, with studies in science education in rural settings very scarce (Panizzon, 2012). To the best of my knowledge, there has been no research undertaken in science education that has exclusively focused on small schools, in particular very small rural primary schools. This means that this specific group, which accounts for 10% of the student population of New Zealand primary schools (Education Review Office, 2015), has not been represented within science education research literature in its own right. This situation personally concerns me, as a practising rural school teacher for over 30 years. The majority of my teaching has been spent in senior management positions in medium to large rural schools ranging from 200 to 500 pupils. However, the last 5 years I have been a teaching principal in several very small rural primary schools. Personally, I have found the way a very small school functions, and the way I teach as a result is remarkably different from my experiences of larger schools. This warrants a good reason to explore the culture and learning of science within a very small rural school. The present study attempts to fill this gap in the research literature

1.2 Context

As already explained, this study is on a very small rural primary school, with a focus on how a science initiative influences the attitudes, engagement, skills, and language of the Year 4 - 6 students. The following gives a description of the rural context where this study is located. I then proceed to explain the Chemistry Outreach programme, which is the focus of this school's science programme.

1.2.1 Rural school context

As already mentioned, the research study is located within a very small rural primary school in the South Island of New Zealand. The community involves the rural village and the surrounding hinterland, and has a population of approximately 150 people. The village has a hall, volunteer fire brigade, and the primary school, but no shops, petrol stations or hotels. Hence, the school constitutes one of the few meeting places within the community. At the time of this research (2012), the school community consisted of 12 families and 19 students, with 11 students (decreasing to 9 over the year due to 2 students changing schools) in the senior Year 4 - 6 class and 8 students in the junior Year 1 - 3 class. Schools in New Zealand need 26 pupils to be entitled to two teachers funded by the Ministry of Education. This school was downgraded to a one-teacher school the following year.

This rural community has a unique culture, compared to the cultures of most New Zealand rural communities in the twenty-first century. To explain, in the 1900s the majority of the inhabitants in rural communities were engaged in agricultural employment, either in farming, or farm servicing agencies. The deregulation of New Zealand's agricultural sector in 1984 saw the withdrawal of production incentives, Supplementary Minimum Prices[1] for agricultural commodities, and Government owned farm consultancy services. This resulted in a drop in farming income, an increase in farm amalgamations which resulted in less family owned farms, and a reduction of employment opportunities. Overall, these measures had a negative effect on the economy

[1] The Supplementary Minimum Prices scheme for wool, meat and dairy products was introduced in 1978 to provide farmers with the assurance that they would be protected from unfavourable global market fluctuations which could undermine the financial viability of the New Zealand agricultural sector (Reserve Bank of New Zealand, 1982).

of rural districts, resulting in a steady population shift to the urban areas, and a decrease in school rolls, with the resultant closure of some schools. Diversification became necessary for economic survival, and now at least one-third of rural inhabitants are employed "in tourism, small businesses, recreational activities and community services" (Treeby & Burtenshaw, 2003, p.11). In contrast, the rural community where the research school is located has a traditional farming structure consisting predominantly of family owned farms, all sheep and beef, and no evidence of diversification. It is this homogeneous nature that influences this rural community's culture, that is, the ways of knowing, learning, and doing that are specific to this particular group of people.

1.2.2 Chemistry Outreach

Since 2008, the Chemistry Department at the University of Otago has co-ordinated a Chemistry Outreach programme with the aim of providing Otago primary and secondary schools with hands-on, interactive, meaningful, and engaging science experiences as part of their school learning programme (McMorran & Warren, 2012). The Chemistry Outreach programme is an example of the scientific community working in with schools to enhance students' learning in science as advocated by Sir Peter Gluckman, the Prime Minister's Chief Science Advisor, in his report *Looking Ahead: Science Education for the Twenty-First Century* (2011). The facilitator, Dr Dave Warren, who was previously a Head of Science in a New Zealand secondary school, uses a multiple engagement approach in order to provide in-depth support for schools and teachers. Chemistry Outreach programmes are driven by the needs of the students as determined by the teachers and principals, and are provided free of charge to schools who request them.

The science programme in this study developed as a result of a partnership between the University of Otago Chemistry Department's Outreach Programme and a rural primary school where I was a teaching principal. Dr Dave Warren, the Chemistry Outreach co-ordinator, along with Science Masters and PhD students visited the school to work alongside the students in a series of hands on science activities, experiments, and investigations over the period of a year. The programme for the present study consisted of three phases. It was initially co-constructed primarily between Dave and myself as the classroom teacher, with progressively more input from the students in the second and third phases. The primary aim was to generate students' excitement and interest in science as a curriculum area, to match these students' considerable passion and enthusiasm for competitive sports (Penrice & Sexton, 2013). This programme provided an opportunity to guide and facilitate the development of the students' scientific knowledge and skills, and to utilise this learning within a meaningful, authentic, student-driven context, with the involvement and expertise of the Chemistry Outreach team (see 3.3 and Appendix A).

1.3 The study.

As indicated, there is limited research relating to science education within the New Zealand rural school context. To the best of my knowledge, there is no research that examines New Zealand science education in a very small rural primary school context. This study attempts to address this gap in the research knowledge. Therefore, the purpose of this study is to develop a knowledge and understanding of science education within the culture of a very small rural primary school context. The study takes the stance that rural school culture is much more than a location. Rather, culture encompasses the ways of knowing, learning, and doing that are specific to these specific students, through the influences of their school, their parents, and the community. The research is situated firmly within the rural context and the culture of a very small two-teacher New Zealand rural primary school. The school and community rural micro-culture is influenced by the macro-culture of Aotearoa[2] New Zealand. Consequently, the discussion of the findings need to be read in relation to the school's unique rural culture, and its positioning within the biculturalism of English and Māori in New Zealand society. The following highlights similarities between the culture of this very small school's rural community to the Māori culture, discusses the macro-cultural influences of biculturalism on the school culture and shows how aspects of the Maori culture and the pedagogical principles within *Tātaiako*:

[2] Aotearoa is the Māori name for New Zealand

Cultural Competencies for Teachers of Māori Learners (Ministry of Education, 2011) align with the ways of knowing, learning, and doing of these specific rural students.

Of particular relevance to this study are the similarities between the culture of this very small school's rural community to the culture of the indigenous Māori. Both cultures have a strong affinity with the land (whenua) and people (whānau) through historic, economic, recreational, and social links. There is a strong sense of belonging with supportive, interpersonal relationships amongst the peoples of the Māori community and this rural community. Furthermore, there is a view of education as a collective rather than solely a personal endeavour. In both cultures there is great importance placed on connections between and with people and the land. Relationships are paramount, with an emphasis on people and their relationships with each other and relationships with the land.

The school culture is underpinned by the biculturalism of New Zealand society which acknowledges the cultures of the indigenous Māori as well as the Eurpoean settlers. Te Tiriti o Waitangi/The Treaty of Waitangi was signed by Māori and the British Crown in 1840 and is considered to be New Zealand's founding document. This treaty promised the Māori peoples protection of their taonga (everything of value to Māori) including their lands, languages, beliefs, values, and traditions. As a result, the New Zealand education system is underpinned by "the principles of the Treaty of Waitangi and the bicultural foundations of Aotearoa New Zealand" ensuring "all students have the opportunity to acquire knowledge of te reo Māori me ōna tikanga[3] (Ministry of Education, 2007, p.9). The Ministry of Education has produced a series of publications for teachers emphasising effective pedagogy focused on Māori students achieving educational success as Māori in an attempt to address concerns about the persistent underachievement of Māori students in comparison with other students in Aotearoa New Zealand (Crooks & Flockton, 2000, 2001; Ministry of Education, 2002, 2009, 2011, 2013a). *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011) is one of these publications that endeavours to improve Māori student

[3] Te reo is the Maori language and tikanga are Maori cultural practices. Language and culture are intertwined from the Maori perspective.

learning through the use of culturally responsive pedagogy (see Bishop, Berryman, Cavanagh & Teddy, 2009; Gay, 2000; Glynn, Cowie, Otrel-Cass & MacFarlane, 2010 McKinley, 2005). The competencies espoused in Tātaiako include ako (reciprocal teaching and learning), whanaungatanga (building relationships), manaakitanga (values - integrity, trust, sincerity, equity), tanga whenuatanga (place-based, socio-cultural awareness and knowledge) and wānanga (communication, problem solving and innovation). The competencies contained within this publication are regarded as sound pedagogy, and are used by many school principals and teachers as guidelines for effective teaching and learning for all students to succeed, not just Māori students.

The examination of the cultural competencies in Tātaiako show a strong correlation to the values of strong connections between the land and the people espoused in both the Māori and rural community culture. The competencies of ako, whanaungatanga, manaakitanga and wānanga relate to relationships, and tangata whenuatanga is linked to the land. Tātaiako emphasizes effective pedagogy focused on Māori students achieving educational success as Maori by working within the cultural values of the Māori. The present study takes the view that effective pedagogy for rural students is to focus on achieving success as rural students by working within the students' rural culture. This reinforces the use of Tātaiako as an appropriate approach to understand science education for rural learners.

The study explores nine rural students' involvement in the Chemistry Outreach programme with a focus on understanding rather than merely describing the participants' "lived experiences" (van Manen, 1990, p. 9). In order to gain a more in-depth understanding of science education in rural schools, these experiences are examined in relation to the specific rural culture of these participants through the culturally responsive pedagogy outlined in *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011). This study initially explores the students' experiences of the Chemistry Outreach programme through the dimensions of attitude, engagement, and the use of scientific skills and language. Then it examines the nature of the Chemistry

Outreach programme and the children's experience of it in terms of the programme's cultural fit with the culture of their rural community.

The participants are nine Year 4 - 6 students representing all the students from the senior class of a very small rural school located in Otago, New Zealand. The student data includes focus group interviews and videos of the children involved in science activities, as well as reflective writing and science book covers. Parents of all the students in the school (18), and 13 members of the rural community (total 31 adults) were also interviewed in relation to the culture of this rural area (see 7.3.1).

The main research question in this inquiry is:

- What are rural primary school students' experiences of a Chemistry Outreach programme?

The subquestions are

- How does the student's experiences with a Chemistry Outreach programme change their attitudes towards school science?
- How does the student's experiences with a Chemistry Outreach programme change their engagement with science and their intention to continue with school science?
- How does the student's experiences with a Chemistry Outreach programme change their use of scientific skills and language?
- How does the Chemistry Outreach programme respond to the students' rural context and upbringing?

To best address the research question and its four subquestions, the present study is set within the qualitative research paradigm and uses phenomenological methodology which views learning as involving the heart (feelings), the hand (acting) and the head (thinking) (Henriksson & Friesen, 2012). Examination of the affective domain (feelings) reveals the students' attitudes towards science, the behavioural aspect (acting) indicates the engagement with science, and the cognitive perspective (thinking) reveals the students' use of scientific skills and language. This study acknowledges science learning is not only an individual but also a social activity (Gopnik, 2012; Jadrich & Bruxvoort, 2011). Therefore, student data will be analysed from an individual and collective (social) level. The methodology and data analysis is discussed in more detail in Chapter Three. Underpinning the whole study, there are the extensive literatures of attitudes, engagement, skills, and language within the field of science education, to which I will turn in the next chapter.

1.4 Outline of thesis

In this chapter I have

- provided background information on the importance of science in the twenty-first century, and examined current science education from an international and national perspective;
- described the research context, namely a very small rural primary school, and provided background information about the science initiative, Chemistry Outreach;
- introduced the theoretical framework on which the study is based;
- indicated what I set out to achieve in this study, and how.

The remainder of this thesis is organised as follows. Chapter Two contextualises the study in the literature relevant to students' attitudes towards school science, engagement in school science, and students' use of scientific skills and scientific language. Chapter Three provides a general outline of the theoretical stance taken in this study. The second part of this chapter details the stages of the research process, including participant selection, strategies for conducting interviews and other data gathering procedures, the data analysis process, and ethical considerations.

The following three chapters present the results and discussions of the data. Chapter Four explores the students' attitudes towards school science and the students' engagement with school science, while Chapter Five examines the students' use of scientific skills and scientific language. Chapter Six discusses the results in relation to the micro-culture of a very small rural primary school within the macro-culture of Aotearoa[4] New Zealand, and cultural responsive pedagogy as outlined in *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011). The final chapter presents the recapitulation of the purpose and findings of the research, a discussion of the limitations of the study, problems encountered and lessons learnt, before implications for future research, recommendations, and contributions to current research are presented. Finally, I reflect on how this research has impacted on me personally as a teacher-researcher and a teaching principal of a very small rural school, and then conclude with my final comments.

[4] Aotearoa is the Māori name for New Zealand

CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

The present study explores nine rural primary school students' lived experiences of the Chemistry Outreach programme. It could be presumed that these rural students would already have positive attitudes towards and engagement with science due to the strong science-based focus in agricultural farming that dominated their lives and the lives of their families. However, although these students had a great enthusiasm for participating in competitive sports, the challenge for me as their teaching principal was to ignite a similar passion for science. The Chemistry Outreach programme studied here was designed to present science as relevant, useful, and meaningful to the students' lives as a way of positively influencing their attitudes to science. Furthermore, the programme presented science in an enjoyable way, with an opportunity for students to participate in the planning, designing, and doing of scientific investigations to encourage the students to become engaged in scientific activities. Finally, the programme gave the students an opportunity to develop their confidence in using scientific skills and language within authentic learning contexts. In summary, the Chemistry Outreach programme focused on aspects of attitude, engagement, and the use of scientific skills and language.

As the review will show, attitude, engagement, and the use of scientific skills and language are important dimensions of science education and have the potential to influence students' experiences of science in both short-term and long-term ways. Attitude can influence immediate and future behaviours with negative attitudes towards science resulting in a lack of interest in secondary school science or pursuing a career in science (Reid, 2006). Engagement is essential for successful science learning and achievement (Fredricks, Blumenfeld & Paris, 2004; Furlong & Christenson, 2008). The use of scientific skills demonstrates an understanding of science and how it works (Skamp, 2015). Scientific language is essential to the doing, learning, and explaining of science (Gee, 2004; Hackling, Smith & Murcia, 2010; Roth, 2005b). Scientific skills and language are useful in students' everyday, civic, and future professional lives, as they aid in making informed decisions about science related challenges and issues of the twenty-first century such as global warming, sustainability, and genetic modification. The present study will investigate the effect of the Chemistry Outreach programme on the students' attitudes, engagement, and use of scientific skills and language. These dimensions fit within the phenomenological stance which views pedagogy as encompassing the heart (feelings), the hand (acting), and the head (thinking) (Henriksson & Friesen, 2012). Therefore, this study will investigate the affect of the Chemistry Outreach programme on the students' attitudes (feelings), engagement (acting), and use of scientific skills and language (thinking). The findings are then discussed in relation to the students' rural culture within a culturally responsive pedagogy framework (see 3.1.3)

As this review will show, there is a lack of research focusing on primary school science students' attitude, engagement, skills, and language within the one study. This study seeks to fill this gap in the literature by presenting more of a holistic view of the science student and their learning. Furthermore, no research study has been found that explores an in-depth research into primary science education within the rural context. This study addresses this concern by firmly situating the research within the context and culture of a very small New Zealand rural primary school. It examines the concepts of attitude, engagement, science skills and scientific language separately, first exploring the methodological issues regarding definition and measures, and indicating the position taken by this present study, and second, evaluating previous research relevant to this study to establish what research is still missing and how the present study will fill that gap.

2.1 Attitude

Attitudes can influence behaviour later in life. Negative attitudes towards school science and science in general formed early on in students' schooling careers can persist throughout secondary schooling years and into adulthood, resulting in lack of interest in studying school science or pursuing a career in science (Reid, 2006). Consequently, negative attitudes can have potential detrimental effects on personal and national prosperity (Osborne et al., 2003), as there is a strong correlation between a country's economic well-being and the numbers of science professionals, such as engineers and scientists (Eilks, Nielsen & Hofstein, 2013).

There has been substantial research into students' attitudes towards science over the past 50 years, mainly focusing on the secondary school, or the years immediately prior to secondary school (Bolstad & Hipkins, 2008; Osborne et al., 2003; Martin, Mullis & Foy, 2009; Martin, Mullis, Foy & Stanco, 2012). Current research agendas are driven by the increasing concern about students' declining interest to specialise in science at secondary school, and to consider science as a career option, evident in many Western countries (Bull et al., 2010; Tytler et al., 2008). This concern is also apparent in New Zealand. The Ministry of Research, Science and Technology (MoRST) consider New Zealand's economic well-being to be directly related to scientists' input into the development and expansion of scientific and technological industries (MoRST, 2010). Consequently, one of their main strategic priorities is to involve more New Zealanders in science.

2.1.1 Definition

Attitude is a complex, multidimensional concept that is often not clearly defined within research studies (Barmby, Kind, & Jones, 2008; Bennett, Rollnick, Green & White, 2001; Logan & Skamp, 2008). This can lead to uncertainty about which aspects of attitude are under investigation within research studies (van Aalderen-Smeets, van der Molen, & Asma, 2012; Blalock, Lichtenstein, Owen, Pruski, Marshall, & Toepperwein, 2008). Two major concerns regarding definition dominate the field of research into attitudes in science education.

First, there needs to be a clear distinction between the concepts of scientific attitudes and attitudes towards science, as these concepts are often used interchangeably (Osborne et al., 2003; van Aalderen-Smeets et al., 2012). Scientific attitudes refer to the skills or mindsets that typify scientific working and thinking such as curiosity, open-mindedness, honesty, challenging assertions, respecting others who have differing opinions, seeking verification, and valuing logic (Domènech & Márquez, 2013). These skills, which help to develop scientific knowledge and understandings, are inherently cognitive in nature, whereas attitudes towards science involve the affective domain of feelings and emotional reactions. Describing science as fascinating and fun is considered an attitude towards science. In this present study, the research focus will be on students' attitudes *towards* school science, specifically the science initiative programme in partnership with the Chemistry Outreach Team (see neon.otago.ac.nz/chemistry/Outreach).

Second, there is no universal agreement on the specific dimensions that make up the concept of attitude towards science. There can be a considerable overlap with other terms such as feelings, values, beliefs, interest, views, motivation, enjoyment, self-esteem, and anxiety (Kind, Jones & Barmby, 2007; Ramsden, 1998).

Attitude is generally defined as a response toward an object, as a result of gaining knowledge and beliefs about that object, which may lead to certain behaviours (Barmby et al., 2008; Kind et al., 2007). It follows then that attitude towards school science would encompass the experience of school science, any feelings an individual may hold towards school science as a result of this experience, and any possible consequential actions or decisions that may occur. Implicit in this definition is the recognition of three components of attitude: the cognitive, the affective and the behavioural. Reid (2006) describes these as "a knowledge about the object, the beliefs, ideas component (cognitive); a feeling about the object, like or dislike component (affective); and a tendency-towards-action, the objective component (behavioural)" (p. 4).

Some researchers view the cognitive, affective, and behavioural components to attitude as interlinked (see for example Caleon & Subramaniam, 2008). To illustrate, if students have experienced school science, they will develop some knowledge of school science and what learning science entails for them (cognitive). Consequently, they may form positive or negative feelings towards school science, and how they see themselves in relation to learning science (affective). Finally, it is the combination of the experience and the response to the experience, which may cause students to choose certain actions. These may include short-term decisions such as choosing whether to participate fully in science experiences, or more long-term decisions like deciding if they are going to take science at secondary school, or pursue a science related career (behavioural).

Other researchers, however, prefer to confine their definition of attitude exclusively to the affective component, independent of any behavioural and cognitive components (e.g., Hill, Atwater & Wiggins, 1995; Francis & Greer, 1999). Attitudes are viewed as the result of evaluative judgements towards an object (Ajzen, 2001; Crano & Prislin, 2006; Petty, 2012). Therefore, students' attitudes towards an aspect of science are a consequence of their judgement according to emotional aspects such as being enjoyable or not enjoyable, favourable or unfavourable. The definition of attitude towards school science used within the context of this present study is based on the affective component, namely the favourable or unfavourable feelings students have towards school science, specifically the Chemistry Outreach programme.

2.1.2 Attitude measures

The most commonly used data gathering approaches to measure students' attitudes towards school science include: subject preference ranking; interest inventories; subject enrolment; attitude scales; and qualitative methodologies (Osborne et al., 2003). I consider subject preference ranking, interest inventories, and subject enrolment, as more applicable to the secondary rather than primary school level. The following describes each of the attitude measures and explains how the New Zealand primary school system makes some of these measures problematic.

Subject preference ranking involves students rating school subjects in order of preference, to establish a comparison of science with other subject areas. To illustrate, a British study examining 362 Year 7 students' school subject preferences found science ranked below Art, Physical Education, English and Drama (Colley & Comber, 2003). However, this approach is a snapshot only, and therefore is not relevant for measuring attitudinal change over time. Furthermore, it is more suited to secondary school systems, as the integrated curriculum topic or inquiry approach prevalent in many New Zealand primary schools may make it difficult for Year 1- 8 students to identify the science aspects in their curriculum programme (Bull et al. 2010).

Interest inventories involve students indicating their preferences from a list involving categories such as students' interest in specific science activities or themes. However, information gathered is generally confined to the parameters of the selected area under investigation thereby producing a somewhat restricted impression of what may help shape attitudes to science (Osborne et al., 2003). *The New Zealand Curriculum* (Ministry of Education, 2007) is not prescriptive, but allows for schools and their communities to choose from broad guidelines of science concepts and skills. Consequently, schools' science programmes are applicable to their particular school and community, resulting in a wide variation in programmes between schools. Therefore, if undertaking interest inventories, each school would require its own unique set of parameters, making comparisons between schools difficult.

Subject enrolment is another avenue of attitudinal information. This is more applicable for the secondary school level, as *The New Zealand Curriculum* (Ministry of Education, 2007) requires all Year 1-10 students to participate in science programmes that include the overarching strand (the Nature of Science) and all the four contextual strands (Living World, Planet Earth and Beyond, Physical World and Material World). It is not until Year 11 that students have the option to specialize within science disciplines, for example, biochemistry, physics, chemistry and/or electronics. Furthermore, the relevance of this method as an exclusive indicator of attitude can be somewhat questionable, especially as other variables such as peer pressure, economic factors, and subject availability could influence students' subject choice (Osborne et al., 2003; Taconis & Kessels, 2009**).**

Attitudinal scales are the most frequently used methods for sourcing data on students' attitudes (Kind et al., 2007; Osborne et al., 2003). The most common type is the Likert-type scale, which was used in the New Zealand National Education Monitoring Project (Crooks, & Flockton, 1996, 2000, 2004; Crooks, Smith & Flockton, 2008), and the National Monitoring Study of Student Achievement (Ministry of Education, 2013b), and in many international studies (e.g., Dowey, 2013; Ekiz , Sülün & Yurttas, 2009; Haste, 2004; Kaptan & Umit, 2014; Murcia, 2013; Ozel, Caglak & Erdogan, 2013). Likert-type scales involve students indicating their response to opinion statements or questions related to the aspect under investigation using a five-point choice ranging from strongly agree through to strongly disagree. Another variation is the semantic differential scale (Yusoff & Janor, 2014). This involves students judging an object, for instance science experiments, according to given bipolar adjectives such as boring/exciting. A third approach is the differential Thurstone-type scale (e.g., Bennett, Rollnik, Green & White, 2001). Students are required to select the statement that is most similar to their attitude from a list of opinion statements on a continuum. Although attitude surveys are easy to administer, especially over a large population of participants, they do have the limitations of predetermined categories, and the measurement of attitude at one specific time only, without the opportunity to indicate reasons that influenced students' attitudes towards science.

Numerous studies have identified potential shortcomings with many of the attitude measurements, especially within the quantitative methodological approach (Barmby et al., 2008; Bennett & Hogarth, 2009; Bennett et al., 2001; Blalock et al., 2008; Francis & Greer, 1999; Kind et al., 2007; Koballa & Glynn, 2007; Osborne et al., 2003; Ramsden, 1998; Reid, 2006, van Aalderen-Smeets et al., 2012). Several areas of potential problems include issues regarding the "lack of precision over definitions of key terms, poor design of instruments and of individual response items within instruments, failure to address matters of reliability and validity appropriately, inappropriate analysis and interpretation of data, lack of standardisation of instruments" (Bennett et al., 2001, p. 834). Consequently, it can be at times difficult to interpret, replicate, or compare the results with other studies (van Aalderen-Smeets et al., 2012; Barmby et al., 2008). For instance, there can be some difficulty in establishing exactly how positive or negative the students are in some studies (Barmby et al., 2008; Osborne et al., 2003). In a study by Hendley, Parkinson, Stables and Tanner (1995), there was no indication by the researchers as to whether 3.26 on a five point Likert scale is measured as positively or negatively (Osborne et al., 2003). Reviewers caution against the practice of some researchers' use of "a summated rating technique to produce a unitary score" (Osborne et al., 2003, p. 1058) which is then analyzed. Such a method can overlook the fact that a meaningful attitude score needs to accurately indicate a student's position on a continuum whereby all the items relate to a single attitude component not multiple components of attitudes towards science. As a result, meaningful details may be lost that could help to identify the main variables affecting attitude (Reid, 2006).

The quantitative (positive) paradigm has been used in the majority of research studies on attitudes towards science. An advantage of quantitative research is the generalizability of the findings, which are focused on the identification and description of the nature of the problem. However, this approach, often through questionnaire type surveys, can tend to restrict the focus of students' answers towards predetermined categories (Lyons, 2006). On the other hand, qualitative research offers the opportunity to study attitude within the context of its use, including any underlying influences. This has the possibility of exploring meanings and explanations to arrive at a deeper and richer understanding of students' attitudes towards science (Lyons, 2006; Osborne et al., 2003). As a result there has been a limited but growing interest in the use of qualitative methodologies recently (Bennett & Hogarth, 2009; Lyons, 2006). These explore students' attitudes through interviews (e.g., Raved & Assaraf, 2011), and focus groups (e.g., Mallow, Kastrup, Bryant, Hislop, Shefner & Udo, 2010).

This present study takes a qualitative approach to exploring the influence of the Chemistry Outreach programme on students' attitudes towards school science through focus group interviews, students' reflective writing, and any comments they made on the designs they created for the covers of their science books. The students are regarded as active participants in the experience and described their affective response towards the programme in their own words. Therefore, the focus is on the students' discourse in and about the Chemistry Outreach experience, in order to establish the influence this programme had on their attitudes towards school science.

2.1.3 Research findings

The previous sections have highlighted methodological concerns regarding the definition of attitude and measurement tools in many of the research studies about student attitudes towards science. It would be prudent at this stage to acknowledge the way schools are organized in different countries. In New Zealand, primary schooling involves Year 1 - 8 students with some Y1 - 6 schools contributing to intermediate schools (Year 7 - 8 only), or area schools (Y1 - 13). Hence, secondary school generally refers to the Y9 - 13 levels. However, it has been noted that the first three years of secondary schooling in English system are Y7 - 9 with pupils aged from 11 - 14 (Barmby et al., 2008). In Western Australia secondary school starts at Year 8 (Speering & Rennie, 1996). In America, 7th grade is typically referred to being part of middle school (George, 2000). Therefore, to avoid confusion, reference will be primarily made to the year groups as equivalent to the grade levels. If primary or secondary school is mentioned, there will be a corresponding year range indicated to prevent any possible misunderstandings.

There are some strong themes that have emerged if one examines carefully which aspects of attitude have been under investigation and how the data has been analyzed. Research studies have shown an increasing decline in students' attitudes towards school science over the duration of their schooling experience, with the decline more evident during the Year 9 - 13 secondary school years (Francis & Greer, 1999; Jenkins & Nelson, 2005). Studies indicate that this decline is becoming apparent at the Year 6 - 9 primary-secondary interface (Barmby et al., 2008; George, 2000; Kind et al., 2007) with Year 7 - 9 (the ages of 11 and 14 years) showing the most significant decline (Bennett & Hogarth, 2009). In contrast to the majority of studies investigating student attitude at this age, a longitudinal study of 20 Australian students found the majority of this group kept their positive attitudes towards school science over their Year 6 - 7 schooling years (Logan & Skamp, 2008). This was attributed to the combination of teaching style, student-teacher relationship within the classroom learning environment, and most importantly, the input of student voice with regard to effective science pedagogy.

It is disturbing to note that there are New Zealand studies that confirm a similar decline in attitudes towards science during the Year 6 - 9 years of schooling. Using attitudinal questionnaires and focus group interviews, Bowmar (1997) found student attitude declined during the latter part of primary schooling in Year 8. Evidence from the National Education Monitoring Project (NEMP) also indicates a substantial decline in positive attitudes in Year 8. NEMP assessed and reported on the achievement of a random sample of approximately 1400 Year 4 and Year 8 New Zealand students in science every four years from 1995-2007 (Crooks, & Flockton, 1996, 2000, 2004; Crooks, Smith & Flockton, 2008). As part of this project they also administered a survey, which sought information on students' attitude towards science. The Year 4 results across the four sample rounds (1995, 1999, 2003, 2007) indicated approximately two thirds (60%; 67%; 62%; 64%) of the students had responded very favourably to the question "How much do you like science at school?' In contrast, approximately a third of the Year 8 students responded very favourably over 1995-2003 surveys (33%; 37%: 32%) and dropped to just below a quarter (24%) in 2007. However, caution needs be taken in reading these results as NEMP have found that Year 8 students have a tendency "to be more discerning and critical" (Crooks, Smith, & Flockton, 2008, p. 57) and are therefore often more liable to select the less positive options. In their analysis of the data, Bolstad and Hipkins (2008) included the results from the two most positive categories (92%; 85%; 83%; 63%) and concluded there was no dramatic decline until 2007. Essentially, it can be argued that Year 8 students are increasingly unenthusiastic about school science. These results are in contrast with the findings of a New Zealand study, which found girls' attitudes towards science improved from Year 7 results after the transition to a girls' only secondary school in Year 8 (Whitten, Tuck & Haig, 2003). This was attributed to strong student-teacher relationships, and a pedagogical style which included practical hands-on activities, built on prior experiences, encouraged student talk, and did not emphasize large amounts of note taking. Furthermore, the girls-only environment where teachers could focus on topics and learning styles that interested girls was identified as a possible factor influencing the girls' attitudes.

Of particular relevance to this study is research indicating that a positive attitude towards science may be starting to decline even earlier than Year 6 (Murphy & Beggs, 2001, 2003; Pell & Jarvis, 2001). Studies of Year 1- 6 students (Pell & Jarvis, 2001) and Y3 - 6 students (Murphy & Beggs, 2001, 2003) showed a consistent year-by-year decline in attitude towards science. A survey of Year 5, 7 and 10 American student attitudes indicated attitudes towards science did decline between Year 5 and 10, even though there was no substantial decline in attitude to school during the same period (Morrell & Lederman, 1998). An Australian study of 264 Year 5 to Year 10 students found a significant decline around Years 6 - 7, however the parameters of the research meant it was not able to establish if there was a decline prior to Year 6 (Skamp & Logan, 2005).

New Zealand evidence indicates positive attitudes towards science at the Years 4 and 5 level. As already discussed, NEMP results from 1995-2007 and 2012 NMSSA results demonstrated a very positive attitude from New Zealand Year 4 students (Crooks & Flockton, 1996, 2000, 2004; Crooks, Smith & Flockton, 2008; Ministry of Education, 2013b). This positive trend continues into the Year 5 group as evidenced in the Trends in International Mathematics and Science Study (TIMSS) 2006/07 results where 84% of Year 5 students enjoy learning science and 82% like science (Crooks et al., 2008). However, the latest TIMSS results reveal a decline, with only 55% of Year 5 students liking science (Martin et al., 2012).

Many research studies have identified a variety of factors influencing attitudes towards science. TIMMS, a large-scale international research study conducted across 60 countries every 4 years, has consistently identified since 1994/5 a strong link between positive student attitudes towards science and high achievement in this curriculum area (Martin et al., 2012). This correlates with the findings from a meta-analysis involving 288 studies of students' attitudes towards school, which found a strong relationship between positive attitudes towards science and mathematics and high achievement in these curriculum areas (Hattie, 2009).

Internal factors including students' achievement motivation, interest levels in science, self-perceptions of their abilities in science, and the perceived difficulty of science have all been identified as contributing towards the development of student attitudes (Lindahl, 2003; Lyons, 2006; Osborne et al., 2003). Furthermore, external factors such as student-teacher relationships and the learning environment can influence students' attitudes towards science. These factors are discussed next.

Of particular interest to the present study is Darby's (2005) year-long study of Australian Year 7 students, examining students' perceptions of engaging pedagogy within the science classroom. It is pertinent to note that Darby's use of engagement is synonymous with affective response for attitude used in this study. The results revealed teachers are perceived to influence student learning through relational and instructional pedagogies. Relational pedagogies, which included the teacher's passion for science and science teaching as well as providing a comfortable, friendly, supportive, and non-threatening learning environment, were as important as instructional pedagogies, which consisted of the teacher's use of explanation, discussion and clarification to help develop students' scientific understandings.

The importance of positive student-teacher relationships and supportive learning environments has been identified in numerous studies as playing a very influential role in the development of student attitudes (Osborne et al., 2003; Simpson & Oliver, 1990). Teacher attitude and encouragement of science was found to have a positive effect on students (George, 2000, 2006). Enthusiastic teachers, who made science fun and incorporated a sense of humour into the lessons, helped develop a relaxed classroom environment conducive to students' learning (Logan & Skamp, 2012; Palmer, 2007). Furthermore, teachers who were interested in science, children's learning of science, and interacted positively with the children during the science lessons had a positive effect on student attitudes (Darby, 2005; Speering & Rennie, 1996).

2.1.4 Evaluation of the Literature - What research is missing?

The studies reviewed so far indicate a general decline in students' attitudes towards science evidenced mainly in the older age groups (e.g., Barmby et al., 2008; Francis & Greer, 1999; Jenkins & Nelson, 2005), but some research is indicating this progressive decline starts within the younger age groups (e.g., Murphy & Beggs, 2001, 2003; Pell & Jarvis, 2001). The New Zealand data points to positive attitudes in Year 4 (Crooks & Flockton, 1996, 2000, 2004; Crooks et al., 2008; Ministry of Education, 2013b) and Year 5 (Caygill, 2008), but these positive attitudes decline by Year 8 (Crooks & Flockton, 1996, 2000, 2004; Crooks et al., 2008; Ministry of Education, 2013b).

The science experiences students have in the primary school years are critical in the formation of positive attitudes towards science (Pell & Jarvis, 2001; Osborne & Dillon, 2008; Tai, Liu, Maltese & Fan, 2006). This points to urgency in researching the area prior to Year 8 in order to understand the decline in positive attitudes evidenced in the New Zealand literature.

There is scarcity of research examining New Zealand students' attitudes towards science prior to Year 8, especially in rural New Zealand. Furthermore, there is a lack of longitudinal studies that study New Zealand students' attitudes towards science within the context of a school based science programme, in order to show any changes in attitude over time. This study will fill this gap in the research literature by examining the influence of a year-long Chemistry Outreach programme on Year 4 - 6 rural school students' attitudes to science. This will afford the opportunity to examine any changes in students' affective responses towards the science programme over time, and possible factors of influence.

2.2 Engagement

Student engagement is essential for successful learning and achievement within the schooling system (Fredricks, Blumenfeld & Paris, 2004; Furlong & Christenson 2008; Shernoff, Csikszentmihalyi, Schneider & Shernoff, 2003). There is a strong link between student disengagement with school and the high drop out rates from the schooling system. Often these disengaged students leave school without the necessary qualifications to ensure purposeful employment and the possibility of tertiary educational opportunities (Finn & Zimmer, 2012; Rumberger & Rotermund, 2012; Wylie & Hodgen, 2012). Limited employment and educational opportunities can result in an increased likelihood of financial hardship, substandard fitness, and well being, and associations with the criminal world, especially for youth from disadvantaged, lower socio-economic backgrounds (Fredricks & McColskey, 2012). On the other hand, student engagement can lead to positive educational outcomes, which in turn can open up employment prospects with financial recompense, thus building a solid foundation for the possibility of a prosperous, successful life after school (Newton & Newton, 2011). It would follow that student engagement is critical for personal and national economic and social well-being.

The majority of the international research investigations into student engagement over the past two to three decades have been driven by two agendas: the prediction and prevention of student dropout; and the improvement of student outcomes primarily within the academic realm but also within the social, behavioural and emotional domains (Appleton, Christenson & Furling, 2008; Reschly & Christenson, 2012). Many countries have implemented educational policies and curriculum frameworks to address concerns with first, secondary school students leaving school early with limited qualifications, and second, raising student achievement. These educational policies emphasize all students must succeed, such as the American 'No Child Left Behind' (Cleary, 2004).

The New Zealand educational scene also has a concerning number of students leaving secondary school, often earlier than desirable, and without basic qualifications. The *Ministry of Education Statement of Intent 2014-2018* (Ministry of Education, 2014) acknowledges the need for a skilled workforce to ensure the nation's ongoing economic growth and prosperity, and has set the target of 85% of 18 year olds achieving National Certificate of Educational Achievement Level 2 or an equivalent qualification by 2017. There is also an emphasis on raising achievement for all students within the New Zealand educational sector. The statement of official policy in relation to teaching and learning for Years 1-13, *The New Zealand Curriculum,* (Ministry of Education, 2007) is underpinned by the belief that "the curriculum supports and empowers *all* students to learn and achieve personal excellence, regardless of their individual circumstances" (Ministry of Education, 2007, p. 9, emphasis added). New Zealand primary schools are accountable in demonstrating student achievement in relation to National Standards in Mathematics, Reading, and Writing (Ministry of Education 2009c; Ministry of Education, 2009d). Accordingly, there is a government target requiring 85% of primary school students to meet the National Standards in Mathematics, Reading, and Writing by 2017 (Ministry of Education, 2014). At present, there are no National Standards in Science, but schools report to their school communities and the Ministry of Education on student science achievement.

This study focuses on student engagement within the situated context of a classroom-learning programme, as opposed to engagement with school or science in general. It specifically examines the influence of the Chemistry Outreach programe on the engagement with school science by Years 4 - 6 primary school students. Although the research literature unanimously agrees student engagement plays a key role in student success (Fredricks et al., 2004; Furlong & Christenson, 2008; Shernoff et al., 2003), there is still considerable debate regarding the definition and measurement of engagement.

2.2.1 Definition

The variety of terminology for engagement used in research has led to ambiguous definitions (Dunleavy, Milton & Crawford, 2010) and "conceptual haziness" (Appleton et al., 2008, p. 382). In some research literature, the referent for engagement is specifically named, for example, positive conduct within the school system (Finn 1993), student engagement with school generally (Appleton et al., 2008; Fredricks et al., 2004), student engagement with subject matter (Marks, 2000 - mathematics and social studies; Guthrie & Wigfield, 2000 - reading; Lee & Anderson, 1993 - science), or engagement in learning (Kennish & Cavanagh, 2009). The following discussion will focus on student engagement with respect to learning, as opposed to engagement with school in general.

Although there is consensus that engagement is a multidimensional construct, there is no universal agreement as to the number and types of dimensions of commitment to learning (Appleton et al., 2008; Fredricks & McColskey, 2012). Engagement studies generally use a range of two to four dimensions to conceptualize engagement. Proponents of a two-component model of engagement include a behavioural (e.g., effort, positive conduct, and participation in learning tasks), and an emotional (e.g., positive emotions, interest, belonging, and value) dimension (Marks, 2000; Skinner, Kindermann & Furrer, 2009; Skinner, Marchant, Furrer & Kindermann, 2008). More recently, researchers have used a tripartite conceptualization of engagement encompassing a behavioural, emotional and cognitive (e.g., investment in learning, strategy use, self-regulation, learning goals) dimension (Fredricks et al., 2004; Guthrie & Wigfield, 2000; Jimerson, Campos & Greif, 2003; Wigfield et al., 2008). This three-part typology is the most commonly used in engagement research literature (Lam et al., 2014). Lastly, Christenson and colleagues (Appleton et al., 2006; Reschly & Christenson, 2006a, 2006b) have conceptualized engagement as containing four dimensions: behavioural, emotional, cognitive and academic (e.g., time on task, completion of learning tasks, earning credits towards qualifications).

There is variability across studies in the way researchers interpret each dimension. For this reason, some researchers have viewed the inclusion of the academic dimension into the conceptualization of engagement with caution, considering it could overlap some already defined dimensions. For instance, academic aspects such as time on task could be construed as a behavioural dimension of engagement (Lam et al., 2014). Reschly and Christenson (2012) also acknowledge possible confusions between interpretations by noting that although Finn (2006) interpreted relevance as emotional engagement, they would consider it as cognitive engagement.

Often, the terms interest and engagement are used interchangeably, particularly concerning student behaviours of maintaining concentration, paying attention, asking questions, and contributing to class or group discussions (Fredricks et al., 2004; Swarat, Ortony & Revelle, 2012). However, there is not necessarily a direct correlation between interest and engagement. While it may seem logical to assume that a high level of interest corresponds to a similarly high level of engagement, some studies have shown off-task behaviour by students who were interested in the subject matter (Ainley, 2012; Swarat et al., 2012) and conversely, students considered to be engaged were found to be thinking of other matters rather than the topic on hand (Peterson, Swing, Stark, Su & Waas, 1984).

A major criticism of the different conceptualizations of engagement focuses on the difficulty of establishing direct correlations between observable or reportable data and the dimension of engagement. As already discussed, students can give the appearance of being engaged whilst involved in off-task activities or thinking. Physical participation does not automatically guarantee engagement with the subject matter (Linnenbrink & Pintrich, 2003). Therefore, overt behaviours could indicate behavioural engagement, despite the possibilities of underlying disengagement. There is a similar concern regarding psychological or emotional engagement. Students may feel positive and therefore emotionally engaged with the subject matter, but this may not necessarily lead to student learning and achievement (Skinner & Belmont, 1993).

The lack of a universally agreed definition of engagement in the research literature is acknowledged in this study. Hence, the concept of engagement needs to be explicitly defined in order for the findings to be understood relative to the type of engagement under investigation. This study ascribes to the view that defining engagement narrowly will add precision and clarity to the research thereby enhancing the value and uniqueness of this study's contribution to the research and scholarly community. Furthermore, it is necessary to avoid confusions with the concept of attitude, which is also under consideration within this study. Therefore, this study will focus on the behavioural dimension of engagement, which involves students' participation, persistence, effort and/or attention in relation to school science. These behavioural engagement results will complement the findings from the affective component of attitude (the favourable or unfavourable feelings students have towards school science).

2.2.2 Engagement Measures

A variety of methods have been used to measure student engagement, including the quantitative measures of student self-report surveys, experience sampling techniques, teacher ratings, and the qualitative measures of interviews, and observations. The most frequently used method for investigating student engagement is the self-report survey, which involves students choosing the type of engagement behaviours that accurately portray them (Fredricks & McColskey, 2012). This provides a retrospective snapshot of the student's subjective perspective of their science engagement. Many researchers recommend administering self-report surveys for emotional and cognitive engagement due to the inferential nature of gauging these subtypes of engagement through observations or teacher rating of student behaviour (Appleton, Christenson, Kim & Reschly, 2006). However, data can be influenced by the students' failure to accurately remember, and the students feeling compelled to respond in ways they feel would be more socially acceptable, especially if there is no guarantee of anonymity (Fredricks & McColskey, 2012; Hektner, Schmidt & Csikszentmihalyi, 2007; Eccles & Wang, 2012).

The Experience Sampling Method involves students answering survey questions about what they were doing, their mood, and level of engagement at regular intervals throughout the school day (see Hetkner et al., 2007 for a detailed description of this method). This approach acknowledges the temporal aspect of engagement by documenting snapshots of engagement experiences over time to generate a comprehensive view of engagement with science (Eccles & Wang, 2012). The contextual immediacy of this type of data gathering can provide a valuable insight into how students' experiences of engagement can vary within the same context (Hektner et al., 2007; Yair, 2000). This method of measuring affective and cognitive dimensions of engagement can have the possibility of being intrusive during class lessons, but only takes a short time for the student to complete the questions at each interval (Yair, 2000; Uekawa, Borman & Lee, 2007). Limitations of this method include the time commitments by the participants, the responsibility of the participants to be honest in their responses, and the constraints of the limited number of survey items (Fredricks & McColskey, 2012).

Teacher checklists or summative rating scales provide a further technique to gather information on levels of student engagement. There is a variation in the number of subtypes of engagement assessed through teacher report scales. Skinner and Belmont (1993) measured students' behavioural engagement (effort, attention and persistence during the task) and emotional engagement (interest, happiness, anxiety and anger). On the other hand, Wigfield et al. (2008) used a multidimensional approach rating students' cognitive engagement (uses comprehension strategies well), motivational engagement (is a confident reader), and behavioural engagement (reads often independently). Teacher report methods have an advantage over student self-reports for children with limited reading ability (Fredricks & McColskey, 2012). When student self-reports and teacher ratings are used together there is stronger correspondence between the teacher and student results of the behavioural engagement than of emotional engagement. Measurement of emotional engagement through teacher ratings needs to be inferred from observations of behaviour, and are therefore susceptible to students possibly concealing their feelings (Appleton et al., 2006; Skinner, Marchand, Furrer & Kindermann, 2008).

Interviews provide the opportunity for students' in-depth descriptive accounts of how they perceive their engagement in their learning. Student voice can give possible explanations for any variations of levels of engagement within a group of students and also individual students differing levels of engagement over a period of time (Fredricks & McCloskey, 2012). Interviews are not constrained by the possible restrictions of self-report surveys and can often confirm and elaborate on findings from other data gathering sources (Osborne et al., 2003). However, the quality of information gained through interviews is dependent on the skill of the interviewer and the willingness of the participants to provide information rich data (Patton, 2002).

Although observations can be time consuming and are often restricted to a small sample base of students, they do have the two major advantages: first, supplying in-depth information of the contextual factors existing during a range of engagement levels and second, confirming knowledge gathered from other sources such as surveys and interviews (Fredricks & McColskey, 2012). The major concern with observations is the inferential nature of ascertaining levels of cognitive and affective engagement from observations of behaviour (Appleton, et al., 2006; Fredricks et al., 2004).

The effective measurement of student engagement is dependent primarily on the clarity of the definition of engagement and the dimensions under consideration (Lam et al., 2014). Therefore, researchers must ensure their conceptualization of engagement drives the choice of engagement measures (Sinatra, Heddy & Lombardi, 2015). Self-reports have the limitation of focusing solely on the individual and not taking into account how the social setting shapes individuals' engagement. Understanding student's engagement with science needs to take into account both the short term and long term interactions as social and temporal concepts, influenced by the perspective that views "individuals as products of social situations" (Olitsky & Milne, 2012, p. 20). Consequently, this study will examine both the individual and social aspects of engagement, with the data coming from student voice and observations. To address concerns regarding the difficulty of correlating data with the behavioural dimension of engagement, data will consist of both observable (videos of students participating in science activities), and reported data (focus group interviews, reflective writing and science book covers).

2.2.3 Research Findings

There are widespread concerns internationally about students' disengagement with science as evidenced by the declining interest for students to specialise in science at secondary school and to consider science as a career option (Goto, 2001; Lindahl, 2003; Lyons, 2003; Osborne et al., 2003; Tytler et al., 2008). An increasing disillusionment with science among later primary school and secondary school students has been widely reported for instance, in England (Osborne & Collins, 2001); Ireland (Varley, Murphy & Veale, 2008), Sweden (Lindahl, 2003), Canada (Bordt, De Broucher, Read, Harris & Zhang, 2001), Australia (Lyons, 2003, 2006; Masters, 2006); and Japan (Goto, 2001).

Concerns about students' diminishing interest in school science and science careers are also echoed in the New Zealand research literature, with less interest shown by New Zealand students to specialise in science at secondary school and to consider science as a career option (Bolstad & Hipkins, 2008; Bull et al., 2010; Hipkins et al., 2006). Science was one of the least engaging subject areas for students at age 14 and 16 involved in the *Competent Children, Competent Learners* (Wylie & Hipkins, 2006; Wylie, Hipkins & Hogden, 2008) longitudinal research which started in 1993 to track the development of approximately 500 students from early childhood education through to adulthood.

Evidence from the National Education Monitoring Project (NEMP) indicates a decline in engagement by Year 8 in both short-term engagement and long-term engagement with science (Crooks & Flockton, 1996, 2000, 2004; Crooks, Smith & Flockton, 2008). The Year 4 results across the four sample rounds (1995, 1999, 2003, 2007) indicated well over half the students (66%, 58%, 56%, 71%) chose the highest rating about wanting to do more science at school, with the 2007 result (71%) the highest score out of the four rounds. In comparison, less than half the Year 8 students (47%, 32%, 44%, 39%) indicated they would like to participate in more science. When questioned about their long-term engagement with science, Year 4 results indicated close to half the students (53%. 43%, 46%, 57%) would like to continue learning about science when they grew up, with the 2007 result (57%) the highest score out of the four rounds. The Year 8 results were across three rounds (1999, 2003, 2007) as the 1995 question was worded in a slightly different way so the results could not be directly compared. In contrast to the Year 4 findings, only a third of the Year 8 students (33%, 31%, 34%) indicated they would prefer to keep learning about science when they grow up.

The NEMP evidence indicates a strong pattern of decline in engagement with science from Year 4 (8 year olds) to Year 8 (12 year olds), somewhat earlier than the age of 14 indicated in Australian studies (Tytler et al., 2008). Of particular relevance to this study is evidence that this decline may be starting as early as Year 5. Results from the Trends in International Mathematics and Science Study (TIMSS) 2010/11 indicate that by Year 5, New Zealand students were fairly neutral in their views about science, and displayed less confidence and engagement with school science relative to international findings (Chamberlain & Caygill, 2013).

These studies confirm that New Zealand students are developing strong views about their engagement in school science and in scientific careers long before it becomes an optional school subject in secondary school at age 14. These findings correlate with international findings, resulting in the major recommendation from an international forum on science education in Europe that engagement should be the highest priority in science education for students younger than 14 (Osborne & Dillon, 2008). Findings highlight the importance of emphasizing student engagement with science during the primary school years.

The major theme throughout the research literature findings points to the quality of the students' experiences of teaching and learning as a principal determinant of their short term and long-term engagement with science. Negative experiences of school science resulted in students being reluctant to pursue further science study once it was no longer a compulsory subject within the school curriculum (Lindahl, 2003). Even students who were successful in their science studies did not necessarily chose to continue with science in their later years of secondary school. High achieving Australian Year 10 science students, who initially were keen to pursue a science career, were dissuaded by their less than positive school experiences (Lyons, 2003). Students' negative experiences in science included aspects relating to learning, pedagogy, and content. These aspects are now explored further.

Science learning was reported by many secondary school students to be boring, at times confusing and unnecessarily difficult compared to the other subjects they were studying as reported by Bordt and colleagues (2001) in Canada, Lindahl (2003) in Sweden, Lyons (2003, 2006) in Australia, and Osborne and Collins (2001) in England. The science pedagogy experienced by many students often involved teacher dominated sessions, where there was the use of the teacher and textbooks to transfer knowledge to the students (Lindahl, 2003; Lyons, 2006; Osborne & Collins, 2001; Varley et al., 2008). Often the focus was on scientific knowledge resulting in students having little opportunity to develop skills of scientific investigation in order to answer their own questions (Tytler et al., 2008). The findings from these seminal studies on student science engagement are echoed in more recent literature (Forbes, 2014; Martin, Mullis, Foy & Stanco, 2012; Office of the Chief Scientist, 2012).

Science content was perceived by students to lack relevancy to their own lives, interests and future aspirations. Students were skeptical of its potential to enhance their present and future lives, and they did not experience meaningful access to examples of people who work in science or science related professions (Haste, 2004; Lyons, 2006). Evidence has shown that changes to the curriculum content at secondary level do not necessarily equate to an increase in students choosing to take science in their later secondary schooling or at tertiary level (Aikenhead, 2005). To illustrate, there was a minimal increase in the number of students taking further science study after experiencing a new science course that involved nearly a third of all students in England aged 14-16 (Ratcliffe, Hanley & Osborne, 2007). This indicates reform at the secondary level may prove be too late as there is increasing evidence that students form their decisions regarding future engagement with science before the age of 14 (Bolstad & Hipkins, 2008; Tytler et al., 2008), and even as young as 10 (Murphy & Beggs, 2005). This points to urgency in researching engagement in the primary school years.

To ensure primary school students effectively learn they need to be engaged in and with school science (Skamp, 2007; Tytler, 2003). This signals the importance of identifying factors influencing students' interest in, and engagement with science. The teaching and learning students experience is a significant determinant as to whether students engage positively towards school science (Logan & Skamp, 2012; Tytler, 2003).

Skamp (2007) asserts effective science pedagogy involves interlinked hands-on, minds-on, and hearts-on science experiences to enhance student engagement. Hands-on, practical activities have been found to be students' preferred pedagogical approach in science learning (Abrahams, 2009; Barmby et al., 2008; Speering & Rennie, 1996; Swarat et al., 2012). High levels of engagement have been reported when students participate in hands-on experiments (Murphy & Beggs, 2001, 2003; Osborne & Dillon, 2008), and student-centred scientific investigations (Elliot & Paige, 2010; Logan & Skamp, 2008). Practical, hands-on investigative science resulted in students being engaged during science activities and wanting to do more science at school (Kerr & Murphy, 2012).

Students enjoyed minds-on science activities that encouraged them to think. A study by Bennett and Hogarth (2009) found 11-year-old students enjoy being challenged to think in their science lessons. These findings confirmed an earlier New Zealand research study involving 518 students from one intermediate school (Year 7 and 8) which found the majority of students preferred science activities that had a challenge and got them to think, otherwise they were inclined to find science boring (Bowmar, 1997). Results have shown that exposure to hands-on practical activities and more cognitively challenging activities that provide the opportunity to participate in the discussion of scientific ideas, resulted in greater student engagement compared to the students from the control schools (Mant, Wilson & Coates, 2007). This year-long intervention programme involved 10-11 year old students from 32 large (rolls from 137-505 pupils) semi-rural schools, of which half these schools were control schools who continued with their traditional content-driven programmes.

Hearts-on science experiences help students make personal connections with science learning. Gallas (1995) highlights the importance of building the science learning process from the students' own experiences, because, "if we, as teachers, don't begin to develop the science curriculum based on our knowledge of the children we teach, how will all of our students ever be fully engaged with the world of science" (p. 103). The New Zealand based Learning in Science Projects (LISP), which investigated effective pedagogical practices in science classrooms, also emphasized access to the students' world of experiences, including the students' culture, as the initial starting point for planning meaningful and authentic learning opportunities (Bell, 2005; Hipkins et al., 2002). Research findings show opportunities to discuss their learning helped students make connections with the science they are learning at school to their everyday lives (Aikenhead, 1996; Darby, 2005; Osborne & Collins, 2000). Furthermore, student-directed scientific investigations give students a sense of control and ownership of their learning (Chin & Osborne, 2008).

Another avenue to support students' engagement with science involves partnerships between schools and the science community. A recent Australian study examined the engagement of primary school students within the situated context of a science initiative programme, *MyScience,* which involved mentors with scientific expertise, teachers, and students participating together as a Community of Practice in scientific investigations (Forbes, 2014). The findings revealed, "collaboration, student ownership and active (physical and mental) involvement resulted in high levels of student engagement" (p. 274). Similar initiatives in New Zealand are documented in the final report on *Strengthening Engagements between Schools and the Science Community* (Bolstad & Bull, 2013). Primary school orientated programmes include the Chemistry Outreach programme (the programme under investigation in this research), the New Zealand Marine Studies Centre, and The Clinic in Wellington. The findings revealed increased student engagement due to the hands-on authentic experiences, access to the expertise of the science mentors, and the opportunity to view 'real' scientists in action (Bolstad & Bull, 2013).

In summary, the encouragement of students' active (physical and mental) involvement with scientific ideas, the development of meaningful understandings, and links to students' lives, interests, learning needs and their local and broader community are key pedagogical influences in increasing students' engagement with science.

2.2.4 Evaluation of the literature - What research is missing?

Engagement is a dynamic entity, influenced by aspects of time and space, and therefore susceptible to change (Uekawa et al., 2007). There are few longitudinal studies of student engagement in primary school science education, with many studies of engagement using one-off surveys or observations over a short period of time, thereby giving the impression of engagement as a static phenomenon (Fredricks et al., 2004; Logan & Skamp, 2008). As a result, there is little acknowledgement of fluctuations of engagement levels experienced by students over a period of time, and possible factors of influence. Consequently, there is a gap in the literature regarding the receptiveness of primary school students' engagement to contextual changes. This study will attempt to remedy this concern by exploring the influence of the Chemistry Outreach programme on students' short-term engagement and long-term engagement with science over a period of one year as documented from the students' personal reflections and actions within the group context. This will afford the opportunity to examine any changes in students' behavioural responses towards the science programme over time, and possible factors of influence. Furthermore, there is lack of research examining New Zealand students' engagement with science prior to Year 8, especially in rural New Zealand, which this study will endeavour to fill by examining Year 4 - 6 rural school students' engagement with the Chemistry Outreach programme.

2.3 Scientific Skills

Science affects students' everyday, civic, and future professional lives. *The New Zealand Curriculum* (Ministry of Education, 2007) states students learn science so "they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role" (p. 17). This means students will be able to utilize "scientific knowledge and skills to make informed decisions about the communication, application and implications of science as these relate to their own lives and cultures and to the sustainability of the environment " (Ministry of Education, 2007, p. 28). Specifically, students will be able to understand how science operates in the real-life world, make considered judgments as to the trustworthiness of claims, and reach carefully thought out personal decisions based on their scientific knowledge and understandings, and their own personal values, in other words, be scientifically literate (Hipkins, 2012). This entails the understanding and the ability to use scientific skills to construct scientific knowledge based on credible evidence (Monhardt & Monhardt, 2006; Skamp, 2015). There is a direct correlation between scientific literacy and scientific skills (Kaya, Bahceci, & Altuk, 2012). Consequently, scientific skills are essential for all students regardless of whether or not they are intending to continue within the science education field and/or pursue a science-related profession.

Scientific skills are an integral part of primary school science education. Over the last 20 years there has been a change in primary school science thinking from focusing on scientific skills such as observing, inferring and predicting, and/or content knowledge to developing conceptual understandings (Skamp, 2015). These conceptual understandings include not only an understanding of basic science concepts related to scientific content knowledge, but also an understanding of science and how it works. To illustrate, concepts of evidence encompass the ideas that underpin the collection, and interpretation of data in order to produce credible scientific data (Gott & Duggan, 2007). Science is more than learning selected content knowledge as there needs to be an understanding of the process of how the knowledge was developed, before the knowledge itself can be understood (Duschl, Schweingruber & Shouse, 2007; Skamp, 2015).

2.3.1 Definition

Scientific skills are variously referred to as scientific reasoning skills, scientific thinking skills, science inquiry skills, intellectual skills, and critical thinking skills (Padilla, 1990). For the purposes of this study, scientific skills will refer to the science process skills used during scientific investigations, and encompass what scientists do and what they think about when engaged in scientific endeavours (Ambross, Meiring, & Blignaut, 2014; Feasey, 2012; Padilla, 1990). Scientific skills are embedded within the scientific inquiry process, and provide the methods and reasoning strategies for students to make sense of the phenomenon under investigation (Ambross et al., 2014). It should not be assumed that scientists, and by association science students, would necessarily use all these skills, or use these skills in a set sequence during a specific scientific investigation.

The simplest categorizations of the scientific skills involve four skills: observing; communicating; comparing; and organizing/classifying (Ritz, 2007) or six skills: observing; inferring; communicating; classifying; measuring; and experimenting (Friedl & Koonz, 2005). Other categorizations include a three-tier classification of basic process skills: observing; comparing; classifying; measuring; communicating; intermediate process skills: inferring; predicting; and advanced process skills: hypothesizing; defining variables; and controlling variables (Lind, 2005; Charlesworth & Lind, 2003). Scientific skills have also been classified according to the different progressions of scientific inquiry models (Abruscato & deRosa, 2010). Hence, the skills of observing, using space/time relationships, using number, questioning, classifying, measuring and communicating are used to create descriptive models. Inferring and hypothesizing are used for explanatory models, whereas predicting, identifying variables, and designing experimental controls are used in the creation of experimental models.

Scientific skills are generally classified under a two-tier hierarchy of basic and integrated skills (Brotherton & Preece, 1995; Martin, Sexton, & Franklin, 2009; Padilla, 1990). The basic (simpler) process skills are prerequisites for the mastery of the integrated (more complex) skills that often require a combination (or integration) of two or more basic science process skills (Settlage & Southerland, 2007).

	Padilla (1990)	**Brotherton & Preece 1995**	**Colville & Pattie (2002)**	**Settlage & Southerland (2007)**	**Martin et al. (2009)**	**Özgelen (2012)**
Basic Skills						
Observing	✓	✓	✓	✓	✓	✓
Classifying	✓	✓	✓	✓	✓	✓
Predicting	✓	✓	✓	✓	✓	✓
Using number		✓			✓	
Measuring	✓	✓	✓	✓	✓	✓
Inferring	✓	✓	✓	✓		✓
Using space/time relationships		✓	✓			✓
Communicating	✓			✓	✓	✓
Recording/displaying data		✓				
Integrated Skills						
Interpreting data	✓	✓	✓		✓	✓
Controlling variables	✓	✓	✓	✓	✓	✓
Hypothesizing	✓	✓	✓	✓	✓	✓
Defining operationally	✓	✓		✓	✓	✓
Experimenting	✓	✓	✓	✓	✓	✓
Formulating models	✓				✓	✓
Presenting information						✓
Inferring					✓	
Graphing				✓	✓	
Investigating					✓	

Table 1: Skills within the basic and integrated scientific skills categories

There is no universal agreement within the scientific community with respect to which specific skills belong in each category (see Table 1). However, all these skills are involved, to a varying degree, in the working and thinking scientifically required for scientific investigation, namely identifying the problem, designing the investigation, interpreting the evidence gathered and communicating the process (Harlen, 1999). This present study ascribes to this view, and therefore does not dichotomize scientific skills into categories, but regards them as integral parts of the doing and thinking involved in the scientific investigation process.

Scientific skills provide “the foundation for scientific inquiry” (Settlage & Southerland, 2007, p. 32). Research literature links achievement in science with students’ ability in scientific skills (Brotherton & Preece, 1996; Cotabish, Dailey, Robinson, & Hughes, 2013; Öztürk, Tezel, & Acat, 2010). Some researchers in the past have questioned the transferability of these skills to students’ personal and future vocational lives citing limited research evidence (Chapman, 1993; Wellington, 1998). Conversely, others argue the cognitive thought processes that underpin scientific skills are transferable to other curriculum areas (Martin et al., 2009). There is research literature that supports the claim that scientific skills can improve student achievement in reading skills, oral and written communication skills, and mathematics skills (Ostlund, 1998). This can be attributed to the similar intellectual and thinking processes required in each of these curriculum areas (see Martin et al., 2005 for examples of the relationship between science and reading skills). For the same reasons, scientific skills have also been linked with reasoning (Zimmerman, 2007), logical thinking, formal operational skills, critical thinking (Padilla, 1990), and components of creative thinking (Meador, 2003).

2.3.2 Scientific Skills Measures

The majority of studies examining students’ scientific skills are quantitative in nature involving the administration of the same type of test in a pre- and post-test situations. Many research studies explicitly detail the scientific skills measures used and the procedures undertaken to ensure validity of the results (e.g. Bilgin, 2006; Ergül, Simsekli, Calis, Özdilek, Göçmençelebi, & Sanli, 2011; Koksal & Berberoglu, 2014; Simsek &

Kabapinar, 2010; Turpin & Cage, 2004). To illustrate, Bilgin (2006) developed a Science Process Skill test by using 25 items from a test designed by Ramig, Bailer and Ramsay (1995) and 5 items from Gabel (1993). Bilgin's test included the scientific skills of observation, measurement, inference, prediction, operational definition, controlling variables, interpreting data, and testing hypotheses. Validity of the test content was confirmed by a science course instructor, and reliability was established through a pilot study of 861 grade 7 and 8 students with the Cronbach's alpha reliability coefficient .78 (Bilgin, 2006). Similarly Ergül and colleagues (2011) explicitly detailed the scientific skill measure used and stated the Cronbach's alpha reliability coefficient result from a pilot study for the grade 4 - 6 students (0.74) and grade 7-8 students (0.78).

Some measures can have limitations as Williams, Ma, Prejan, Ford and Lai (2007) discovered after using a scientific inquiry measure designed by Ketelhut and Dede (2006). This measure involved students describing a problem scenario presented to them and then developing a hypothesis and procedure to test their hypothesis. Before the publication of their article, Williams et al. (2007) discovered the developers of the test were now querying the ability of the test to detect subtle differences in students' inquiry skills. Williams et al. (2007) surmised that this could in part explain some of the discrepancies in their findings between the qualitative and quantitative data. This highlights the need for ongoing critique of measures used to ensure consistent valid quantitative measures of scientific skills.

Qualitative studies have included a variety of data including student interviews, class discussions and children' written work (Metz, 2004) and videos, field notes of classroom discourse and students journals (Varelas, Piper, Arsenault, Pappas, & Keblawe-Shamah 2014). The use of students' written and/or spoken text dialogue, along with observations, can reveal developing understandings and use of scientific skills, and as such can add depth and richness to the interview data (Varelas, Pappas, & Rife, 2006). This study acknowledges the advantages of qualitative research, and uses focus group interviews and videos of the students involved in scientific activities. The exploration of what the students do, think, and talk, will help give a more complete picture of their developing use and understandings of scientific skills.

2.3.3 Research Findings

Since the 1960s, there has been substantial research into the teaching of scientific skills at both the preschool and primary school levels (Ergül et al., 2011; Molefe & Stears, 2014). Furthermore, there are an increasing number of studies investigating the acquisition of integrated skills by primary and secondary school students (e.g. Knaggs & Schneider, 2012). The following examines the debate regarding when to teach scientific skills, and then explores the research literature regarding factors of influence and finally concludes with possible pedagogical implications.

There is no general consensus as to when the specific scientific skills should be taught. Basic and integrated skills have been shown to correspond respectively to the concrete and formal reasoning stages of Piaget's Cognitive Development Model (Brotherton & Preece, 1995). To illustrate, the identification and control of variables can be viewed as a Piagetian formal reasoning pattern as well as an integrated level scientific skill (Brotherton & Preece, 1995). Proponents of this theory argue the intellectual reasoning required for integrated skills is too sophisticated for primary aged children (Brotheron & Preece, 1995; Kuhn & Dean, 2005). Therefore, the basic scientific skills are regarded as suitable for the preschool and primary school levels (Lind, 2005; Charlesworth & Lind, 2003). Although some researchers consider the teaching of integrated scientific skills as appropriate from grade 3 level onwards (Martin et al., 2009), others recommend starting in the upper elementary grades, cautioning that before the age of eleven years children do not seem to be able to handle the complexity of thought required to use integrated scientific skills (Settlage & Southerland, 2007).

In contrast, other researchers challenge the Piagetian rationale that students require a specific degree of cognitive development before being taught higher-level scientific skills. They consider such an approach places developmental constraints on students' cognitive engagement with scientific inquiry thereby underestimating the complex ways young children can use in their efforts to construct meaning (Klein, 1998; Metz, 2004; Murphy, Bianchi, McCullagh & Kerr, 2013). Furthermore, they believe any attempts to define students' competencies must also include contextual aspects including support such as scaffolding from teachers or peers (Metz, 2004). Consequently, there is growing research literature that demonstrates young children can participate in authentic scientific inquiry, using the more complex integrated skills when needed as part of the investigation, with supportive adult or peer guidance (Varelas, et al., 2014). To illustrate, the skills of predicting, observing and explaining were displayed by preschoolers, aged 3 and 4 years, when involved in scientific inquiry (Peterson & French, 2008). The skills of reflecting on their inquiry design and being aware of how uncertainty can be part of scientific inquiry were demonstrated by grade 2 students (Metz, 2004). Complex reasoning skills were used by 5 and 6-year-old children (Siry, Ziegler & Max, 2011), and grade 1 to 3 students (Varelas, Pappas, Kane, & Arsenault, 2007) as part of their scientific inquiry. A variety of scientific skills including "questioning, hypothesis formation, experimental design, identifying relevant evidence, critical analysis of hypotheses and predictions, hypothesis reconstruction, and variable identification" (Kirch, 2007, p. 785) were evident in grade 2 students' conversations during scientific inquiries. Overall, the research literature supports young children, when given the opportunity and appropriate support, being capable of engaging in more complex scientific skills than previously thought.

Many researchers advocate the teaching of scientific skills within scientific inquiry, emphasizing the need for connections to real-world contexts with multiple opportunities to experience and practice the skills (Monhardt & Monhardt, 2006; Turpin & Cage, 2004). The students are therefore involved in the doing and the thinking scientists would be engaged in whilst conducting their investigations, namely establishing the question to be investigated, gathering relevant information, searching for and testing explanations, and producing scientific knowledge (Chinn & Hmelo-Silver, 2002; Chinn & Malhotra, 2002; Simsek & Kabapinar, 2010). Scientific inquiry provides the opportunity for teaching the purpose and use of scientific skills, and enhancing the understanding of the aspects of how, when, and why these skills are used within a meaningful, authentic context. It follows then that inquiry-based teaching and learning approaches would show a positive effect on students' acquisition and use of scientific skills (Simsek & Kabapinar, 2010; Sullivan, 2008; Wu & Hsieh, 2006).

To illustrate, a study by Simsek and Kabapinar (2010) found an eight week inquiry-based learning programme had a positive effect on 20 Turkish grade 5 students scientific skills, with the most improvement occurring in the skills of measuring, correlating/classifying and forming hypotheses. Unfortunately, the study did not identify the other skills under investigation. In contrast, all the skills under investigation were explicitly stated in a study by Wu and Hsieh (2006) which investigated the effect of a six week inquiry-based programme on 58 Taiwanese sixth graders' ability to identify causal relationships, to describe the reasoning process, to use data as evidence, and to evaluate explanations. The students made significant improvement in identifying causal relationships, describing the reasoning process, and using data as evidence. However, the students demonstrated only a moderate improvement in evaluating explanations due in part to the research design whereby students had less opportunity to practise and discuss these skills with their peers and to receive feedback from the teachers compared to the other skills.

There are a number of comparative studies that demonstrate inquiry-based teaching promotes improvement in scientific skills compared to other programmes, generally more didactic science instruction with a textbook or teacher demonstration approach (Bilgin, 2006; Koksal & Berberoglu, 2014; Tek & Ruthven, 2005; Turpin & Cage, 2004; Yager & Akcay, 2010). Research involving 724 American grade 4 - 9 students found the experimental group involved in an inquiry-based intervention programme showed a significantly greater improvement in the ability to apply scientific skills than the control group who were taught via a traditional textbook method (Yager & Akcay, 2010). A drawback to this study was the lack of identification of the specific skills under investigation.

A study by Bilgin (2006) involving 55 grade 8 Turkish students found students improved in their scientific skills as a result of a 15-week hands-on co-operative learning programme compared to those taught by a teacher demonstration approach. The experimental group discussed open-ended questions, read information related to the scientific skills and did hands-on activities co-operatively in small groups, whereas in the control group the teacher dominated the question session, explained the scientific skills and demonstrated the activities. These results were consistent with a study involving 241 Turkish students over two semesters which found an inquiry-learning approach incorporating hands-on activities significantly enhanced grade 4 - 6 students basic scientific skills and grade 7 - 8 students' integrated scientific skills compared to the traditional demonstration approach (Ergül et al., 2011). Another large scale study of 927 American grade 7 students also found an integrated hands-on inquiry approach was more effective in raising students' capabilities with scientific skills than using a traditional textbook approach which emphasized lectures and teacher demonstrations (Turpin & Cage, 2004).

It is pertinent to mention at this stage that doing practical hands-on science does not automatically result in students developing a deep understanding of scientific concepts and processes. For this type of understanding to develop it is important that activities require students to be engaged both physically (hands-on) and cognitively (heads or brains-on) with the science activities (Osborne & Dillon, 2008; Toplis, 2011). This does not imply that all science activities need to involve physical materials. It is possible to achieve similar results with twenty-first century technology. Several studies have examined the use of educational technologies as a way for students to be actively engaged in inquiry-based authentic science investigations within the science classroom. Technologies that are an integral part of a learner-centred inquiry programme and focus on making science knowledge and skills more accessible within authentic contexts can have a positive impact on students' acquisition of scientific skills (Flick & Bell, 2000).

The use of the Internet can be beneficial in developing students' scientific skills. Web-based learning environments are hypermedia-based programmes conducted using the World Wide Web as a resource (Khan, 1997). A study of 19 grade 5 students over a five-week period in a web-based learning environment showed positive effects on students' acquisition of integrated scientific skills, in particular the skill of controlling variables

(Saat, 2004).

Computer simulations are another example of educational technology that can be used in the science classroom. They consist of, "computer generated, dynamic models of the real world and its processes" and include, "animations, visualizations, and interactive laboratories" (Smetana & Bell, 2012, p. 1338). These simulations offer students the opportunity to undertake complex simulated scientific investigations, which they would not be able to conduct as hands-on inquiries due to the constraints of time and suitable equipment (Chinn & Malhotra, 2002). A recent review of the research literature found computer simulations were effective in developing students' scientific skills (Smetana & Bell, 2012). To illustrate, scaffolded simulation-based inquiry learning was found to have positive effects on grade 5 students' scientific skills (Kukkonen et al., 2014).

Robotic activities are a further example of technology that could have the potential to increase students' capabilities in using scientific skills. Benitti (2012) reviewed recent research literature on the use of robotics in schools and found the results to be somewhat inconclusive regarding the improvement of students' scientific skills. Analysis of the following two research studies support this view. A study by Sullivan (2008) found a robotics approach resulted in an increase in students' ability in the scientific skills related to aspects of variables, hypothesis and solution evaluation. On the other hand, Williams et al. (2007) found although a variety of scientific skills were introduced and practised during the programme, the students often reverted back to a trial and error strategy during their scientific investigations. The results from these studies need to be read with some caution. The interventions were short, intensive sessions of three weeks for the study by Sullivan (2008), and two weeks in the study by Williams et al. (2007). Therefore some students may not have had sufficient time to consolidate the new skills. Another aspect to consider with these two studies is the number of adults in the teaching and assisting role. There were ten facilitators in the study by Williams et al. (2007), and only two adults for the study by Sullivan (2008). Furthermore the participants in Sullivan's study were selected above average ability students, whilst the students in Williams et al. (2007) study volunteered to participate and consisted of students from grade 6 to 8. These aspects make comparisons between studies difficult.

As already indicated there have been many studies that demonstrate positive gains in scientific skills when using an inquiry-based teaching approach. These results however, have limitations, as there is often no indication of the degree of inquiry involved (Anderson, 2002). Inquiry-based learning in the classroom can range from varying levels of teacher-centred through to learner-centred formats (Breerer & Bodzin, 2004). In some research studies aspects such as the teacher role, the student role and the type of student work were not explicitly detailed making comparisons between studies difficult. An exception is a study of 304 Turkish grade 6 students who experienced a guided inquiry programme (Koksal & Berberoglu, 2014). These students made more gains in their scientific skills than the control group students who were involved in the traditional teacher demonstration approach.

The different levels of inquiry can be differentiated depending on the degree of ownership the student has over posing the problem to be investigated, the choice of method, and conclusions (Bell, Smetana, & Biinns, 2005; Breerer & Bodzin, 2004; Hackling, 2005). For example, Bell and colleagues (2005) advocated a 4-level framework of inquiry incorporating the stages of confirmation, structured, guided and open depending on the amount of information provided to the student. The confirmation stage is where the teacher poses a question to be investigated and provides explicit instructions to confirm a result that is already known in advance. Structured inquiry is similar except the students are not given the solution. Guided inquiry involves students choosing their own procedures to investigate a teacher-posed question and thereby coming to their own conclusion. In the open inquiry level, students select their own question/problem to be investigated, design and carry out the procedure and come to their own conclusions.

There has been some research evaluating the different types of inquiry on students' science learning. Most of these studies have involved high school and university students and do not specifically focus on the acquisition of scientific skills (e.g., Chatterjee, Williamson, McCann, & Peck, 2009; Sadeh & Zion, 2009, 2012). An exception is a study by Bunterm, Lee, Kong, Srikoon, Vangpoomyai, Rattanavongsa and Rachahoon, (2014) which compared the effects of guided and structured inquiry approaches on grade 10 and grade 7 Thai students' scientific skills. The guided inquiry approach involved students designing their own procedures to investigate a teacher-presented question, whilst students in the structured inquiry investigated a teacher-presented question through teacher prescribed procedures and were provided textbooks to assist in the data interpretation. The findings demonstrated greater improvements in students' scientific skills when engaged in a guided inquiry approach compared to the structured inquiry.

Some researchers regard many of the inquiry tasks often found in science classrooms as requiring the students to engage in a different cognitive reasoning than is required for authentic scientific inquiry (see Chinn & Malhotra, 2002 for a comparison of the cognitive processes required). They consider true authentic scientific inquiry to be similar to the complexity of reasoning required for open inquiry based on the premise that "scientists reason under uncertainty and that they co-ordinate partially conflicting results from different experiments of different types" (Chinn & Malhotra, 2002, p. 212). It is pertinent to note that in this present study students were involved in a programme that transitioned from structured inquiry, then guided inquiry and finally an open inquiry approach.

A comprehensive literature review in science education noted the lack of classroom research regarding the impact of different types of pedagogy on the students' acquisition of scientific skills and understandings (Hipkins et al., 2002). Since then, there has been a growing bank of research literature showing that there is not a direct cause and effect relationship between the involvement in scientific inquiry and the improvement in scientific skills. As already mentioned merely doing science does not necessarily mean the student is cognitively engaged in science learning. Contextual aspects such as the relative extent of teacher scaffolding and student responsibility and ownership throughout the process need to be taken into account (Metz, 2004). Hence, recent research has focused less on whether inquiry is effective, and more on the implementation of the pedagogical aspects of inquiry learning within a science programme (Anderson, 2002). It is acknowledged that the more independence students have in the inquiry process, in other words, the more open the inquiry format is, the more complex and challenging it can be pedagogically (Wu & Krajcik, 2006). In their study on the effect of a guided inquiry approach on grade 6 Turkish students, Koksal and Berberoglu (2014) concluded the guided inquiry approach could serve as a transition between the traditional teacher-centred approach and more student-centred learning as experienced in an open inquiry approach. This would result in the teachers and students gradual developing confidence and understanding of the process, an approach advocated by Brough (2013).

Research studies that have explored the pedagogical aspects in the acquisition of scientific skills emphasize the appropriate scaffolding by the teacher (Kukkonen et al., 2014; Metz, 2004; Peterson & French, 2008; Wu & Krajcik, 2006). Scaffolding has the potential to "support students to activate schemata, organize and retrieve knowledge, monitor and evaluate, and reflect on their learning" (Ge & Land, 2004, p. 6). In order for the scaffolding to be effective, the teacher needs to be aware of the students' abilities, engage them in authentic practices, and sequence tasks accordingly giving ample opportunities for the students to consolidate their new skills with teacher support. To illustrate, it was found that giving grade 7 American students the opportunity to "discuss, review and clarify questions" (Wu & Krajcik, 2006, p. 63) when designing and interpreting a variety of graphs and tables of increasing complexity in an inquiry-based programme had a positive effect on the students' acquisition and understanding of scientific skills within the science process. Another American study found providing a specific scaffolding tool, in this case a vee-map[5], to construct their scientific inquiry, along with teacher support resulted in positive improvements over time in the students' scientific skills (Knaggs & Schneider, 2011). It is through these processes that the student is gradually socialized into the way of thinking scientifically.

[5] A vee-map is a form of graphic organizer consisting of two interrelated sides, the conceptual side and the methodological side, bordering the central scientific inquiry question in a vee shape. The purpose of a vee-map is to support the students in recognising the connections between the concepts (students' prior knowledge) and the processes (what the students are about to do) involved in scientific inquiry (Knaggs & Schneider, 2011).

The preceding paragraph has emphasized the influence teachers have in students' acquisition of scientific skills (Harlen, 2000). It is noted that researchers using educational technology within inquiry learning situations particularly emphasized that technology did not replace the expertise of the teacher (Kukkonen et al., 2014; Smetana & Bell, 2012). The beliefs and understandings teachers hold about the scientific skills can affect the way they teach them thereby influencing students' perceptions (Wenham, 2005). To illustrate, some teachers can tend towards emphasising scientific content rather than the scientific skills (Molefe & Stears, 2014), often focusing on the correct answer as opposed to exploring a multitude of possibilities in the process of understanding and meaning-making (Ambross et al., 2014). This in effect devalues the importance of scientific skills within scientific inquiry.

2.3.4 Evaluation of the literature - What research is missing?

The majority of studies focusing on primary school students' scientific skills are quantitative in nature and examine interventions that have taken place over a comparatively short period of time. Many studies have been conducted within urban schools and focus on single-level classes. To the best of this researcher's knowledge there is a lack of studies examining the effect of a science programme on rural New Zealand primary school students' acquisition and use of scientific skills. Furthermore, there is a dearth of studies exploring scientific skills within a programme where students transition from a structured to an open inquiry approach.

This present study explores Year 4 - 6 students' use of scientific skills qualitatively through focus group interviews and videos of students engaged in small group hands-on science activities and scientific investigations over a period of a year. As a longitudinal study, it has the potential to reveal the development of the students' acquisition and understanding of the science process skills as they progress from a structured inquiry to an open inquiry approach. The context of this study is a multi-level class (Years 4-6) within a New Zealand rural primary school and thereby presents another perspective on primary school students' acquisition and use of science process skills.

2.4 Scientific Language

Language is fundamental to science as scientific knowledge is "dependent inextricably on language and language is also central to our ability to think [scientifically]" (Evagorou & Osborne, 2010, p.136). Language, in particular talking science, is essential to the doing and learning of science (Gee, 2004; Hackling et al., 2010; Roth, 2005b; Wellington & Osborne, 2001). Lemke (1990) defines talking science as "*doing* science through the medium of language" (p. ix, original italics). Talking science encompasses "observing, describing, comparing, classifying, analyzing, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing, lecturing, and teaching in and through the language of science" (Lemke, 1990, p. ix). It follows that language is vital to science education as a medium through which students can express their comprehension of the scientific knowledge about the natural world, articulate their views about the world, and develop new understandings through the scientific inquiry process (Adúriz-Bravo, Chion & Pujalte, 2015; Carlsen, 2007; Skamp, 2015).

It is through the acquisition and application of the skills to clearly communicate science observations and ideas that students can further develop their scientific thoughts and understandings (Hipkins et al., 2002). Therefore, language plays a vital role in the science classroom by facilitating meaning-making, and consequently the understanding of established science concepts and the development of new scientific ideas (Gee, 2004; Skamp, 2015). In most primary and secondary school classrooms there is generally more emphasis on students gaining mastery of scientific conceptual knowledge than scientific language (Gee, 2005; Wellington & Osborne, 2001; Gallas, 1994, 1995). This can lead to language becoming a major obstacle for students in their learning of science. In fact, Wellington and Osborne (2001) contend that one of the most effective pedagogical strategies a teacher can employ to improve the quality of science education is to focus more on language in the science classroom.

2.4.1 Definition

There is no universal definition of scientific language evident in the research literature exploring language within the science-learning context (Ash, 2008). Studies incorporate a variety of approaches when examining scientific language from the perspective of either verbal language and/or non-verbal language. Verbal language encompasses aspects of the spoken and written word, whereas the non-verbal can include the scientific language present in visual-graphic representations such as models, diagrams, and tables, as well as a range of mathematical processes including measuring, graphing, and calculations (Feasey, 2015; Jones, 2000). These non-verbal representations can add to, or replace, verbal modes of communicating scientific information (Bielenia-Grajewska & Gunstone, 2015). To illustrate, visual representations such as graphs and tables can often summarize information more succinctly than an oral presentation. Other researchers perceive language from a social semiotic perspective and examine language alongside the multiple embodied modes such as hand gestures, body movements, posture, voice tone, facial expressions, and exchanges of glances that accompany the verbal utterances (Roth, 2005c; Taylor, 2014; Tytler & Aranda, 2015; Varelas et al., 2014).

Although there is a lack of consensus regarding the definition of scientific language, there is general agreement that scientific language differs from the language used by students in their everyday life (Gee, 2004; Lemke, 1990; Roth, 2005b). This is evidenced in the variety of terminology used for scientific language and non-scientific language. Scientific language terminology includes: academic discourse (Ash, 2008; Varelas et al., 2007); scientific discourse (Gee, 2004); the language of science (Wellington & Osborne, 2001); non-vernacular language (Brown & Spang, 2008); technical terminology (Jadrich & Bruxvoort, 2011); school-science language (Olander & Ingerman, 2011); specialized language in science (Wenham, 2005; Wenham & Ovens 2010); specialized vocabulary (Dawes, 2004); and scientific language (Olander & Ingerman, 2011; Warren, Ballenger, Ognowski, Rosebery & Hudicourt-Barnes, 2001). In comparison, the language students bring from their life outside school into the scientific classroom is variously referred to as: non-academic discourse (Ballenger, 1997); everyday language (Olander & Ingerman, 2011); everyday discourse (Varelas et al., 2007); unscientific discourse (Wray & Lewis, 1997); lifeworld language (Gee, 2004); informal language (Warren et al., 2001); authentic language (Wallace, 2004); everyday/colloquial language (Olander & Ingerman, 2011); spontaneous language (Ash, 2008); and vernacular language (Brown & Spang, 2008). The following describes the specific ways of talking that are inherent in scientific language to show how it differs from the everyday language students use in their day to day conversations.

Scientific language is a specialized language incorporating a technical vocabulary unique to science, the use of everyday words that take on a different meaning within the science context, and specific grammatical features and discourse patterns that are exclusive to science (Gee, 2005; Lemke 1990; Wellington & Osborne, 2001). The vocabulary of science can be classified into four categories as outlined by Wellington and Osborne (2001).

The first category includes labelling words that rename objects students would be familiar with in their everyday life. An example of this would be using scientific terminology such as vertebra for backbone. This category also includes the labelling of unfamiliar objects that are only experienced in science settings, for instance, bunsen burners, or not able to be seen by students, for example, radiation or Wi-Fi. The second category refers to scientific processes, including those that can be demonstrated or observed, like combustion, and those that are non-observable such as the carbon cycle. The third category includes concept words. Basic concepts are those that can be observed by the students, for example colour and shape, and are referred to as sensory concepts. The next level includes words that have dual meanings, one in the scientific context and the other in everyday life, for instance, power, energy, and work. In other words, science language uses words the students may have used in non-scientific settings. These words have a different meaning when used within the scientific context. This can result in misunderstandings and confusions for students as they grapple with one word representing different ideas dependent on the context. Consequently, the use of everyday language within the scientific context is viewed as a barrier for some students in the learning of science (Wellington & Osborne, 2001). The third level within the conceptual categorization includes theoretical constructs, including unobservable concepts such as molecules. The fourth category involves the abstract representations of scientific phenomena through the words and symbols of mathematics, for example $E=mc^2$.

Scientific language contains many discursive and grammatical structures, such as logical connectives, qualifiers, nominalization and creative literacy devices, for instance, metaphoric abstraction, as well as specific grammatical features (Jones, 2000; Wellington & Osborne, 2001). These discursive structures can assist with the clear, logical communication of science ideas. Logical connectives are words or phrases that link ideas as part of scientific discussion or argumentation. These connectives can be used to highlight contrasting ideas (conversely); identify cause and effect (because, so); establish conclusions (therefore); indicate time sequences (next, after that); or make inferences (on the basis of). Qualifiers are used by scientists to indicate when they are making tentative or cautious conclusions, for example 'some' or 'the majority,' as opposed to definitive generalizations from evidence. Nominalization involves replacing verbs and adjectives with the related noun form, hence absorb becomes absorption, and flexible becomes flexibility. Metaphoric abstraction involves the use of metaphors as simplified depictions of scientific phenomena bridging the divide between reality and the mental representations, for instance referring to the brain as a computer. Scientific metaphors are quite commonplace in science discussion as, "metaphors are at the heart of science; thus we now accept and see the flow of electric charge *is* a current, light *is* a wave and so on" (Jones, 2000, p.93, original italics). Furthermore, scientific language contains the use of some specific grammatical features, especially when reporting or recounting scientific ideas or investigations. These features include the use of the timeless present tense, and general pronouns (we, you) as opposed to first personal singular pronouns (I).

There are two functional roles for language in science (Sutton, 1998). First, language can be regarded as a system for transmitting information by labelling and communicating established scientific knowledge. Second, language serves as an interpretative system of sense-making open to tentative speculations during the process of developing new understandings. Sutton claims there is an overuse of the labelling function in classroom science giving students the impression that science knowledge is a static, factual form of established knowledge. He considers both functional roles are important in the learning of science. The interpretative function of language is the articulation of the science meaning-making process experienced by the students, whereas the labelling role of science language can assist students in the clarity of expression. Consequently, the labelling role can be viewed as a tool to assist in the process of making sense of scientific phenomenon.

Carlsen (2007) further expands Sutton's (1998) framework of the role of language in science. He defines the third role of language as, "a tool for participation in communities of practice" (p. 68). This is based on the premise that science learning is ultimately a sociocultural practice where language is used to persuade, argue, challenge and/or critique the findings of a community of practice. Carlsen (2007) explains that, "it is in the expectation and practice of public argument that science progresses. Conflict is not only permissible, it is necessary" (p.68). It is through this process that new scientific claims can be verified and established (Carlsen, 2007).

This present study examines the influence of a science programme on Year 4 - 6 rural primary school students' use of scientific oral language. While acknowledging the importance of the argumentation role of scientific language (Carlsen, 2007), the focus will be primarily on the labelling and interpretative functions of language in the science classroom (Sutton, 1998). Everyday language will be the terminology used to denote the non-scientific language used by the students, and scientific language will indicate the students' use of technical science language.

The term discourse is often used in research literature examining scientific language. For the purposes of this study, discourse and language are regarded as two separate concepts. Although both language and discourse refer to the use of language within a specific context, discourse is viewed as a more global view of language, encompassing all verbal and non-verbal representational forms of science (Brown & Ryoo, 2008). Therefore discourse can include the consideration of aspects of verbal modes of the spoken, read, and written word, and the non-verbal modes of pictures, diagrams, tables, graphs, drawings and models. Language in this present study will be narrowly defined as one or more spoken words used to represent scientific ideas or concepts.

2.4.2 Scientific Language Measures

The majority of studies examining students' scientific language use a qualitative design methodology. However, the interpretive aspect of qualitative research into language in the science classroom can have a bearing on the reliability of the data analysis. Tytler and Aranda (2015) acknowledged the limitations of their coding framework of student-teacher talk due to the interpretive aspect of qualitative research. However, they compensated for this by using a peer review system to establish consistency within their coding system.

The difficulty of establishing consistent, valid, and reliable measures of scientific language continues to be an ongoing challenge for researchers (Osborne, 2010). More recent trends in the research into science learning and language include aspects of scientific literacy whereby the students use scientific evidence to argue their position. Researchers acknowledge there are challenges in the development of valid and reliable measures of students' argumentation language within the scientific context (Osborne, 2010).

Time constraints can be a factor in scientific language studies. This is understandable in qualitative research studies that involve accessing, transcribing, and analyzing extensive data from student interviews or discussion. However, time was also acknowledged as a constraint within a study employing a mainly quantitative design methodology. Brown and Ryoo (2008) conceded that the lack of time limited the number of multiple choice and open-ended questions in their pre- and post-tests.

Carlsen (2007) advocates for researchers to become more familiar with the skills needed to analyze scientific language data. This sentiment is echoed by Bennett et al. (2010), who specifically identified discourse analysis techniques as an area for consideration when researching small group science discussions. Although there is evidence of discourse analysis being used in studies that involve classroom or group talk with the teacher (Brown & Spang, 2008), and student-teacher talk (Tytler & Aranda, 2015), there is a paucity of research literature that focuses on student only small group discussions that utilize discourse analysis. This present study will address this gap in the literature by using discourse analysis for the data gathered from small group discussions.

2.4.3 Research Findings

There has been increasing research into classroom language and students' learning over the last few decades (see Cazden, 2001; Vygotsky, 1981; Reznitskaya & Gregory, 2013; Wells, 1999). Similarly, the research output in the area of language and science education has been increasing since the early 1970s (Bielenia-Grajewska & Gunstone, 2015; Fenshaw, 2004). A systematic review of the last 40 years of research in classroom language noted the most common curriculum area to be studied was science (Howe & Abedin, 2013). This implies an acknowledgement of the significant role language plays in the learning of science (Bielenia-Grajewska & Gunstone, 2015).

Research studies on scientific language incorporate a range of perspectives (Bielenia-Grajewska & Gunstone, 2015, Maeng & Kim, 2011). One perspective focuses on the content aspect of the language; that is to say, how language is used to communicate scientific conceptual understandings (Brown & Ryoo, 2008). Some studies examine the role of language and socially constructed meaning-making within the scientific inquiry process, where students are involved in collaboratively generating shared explanations, constructing new understandings, or solving problems through group talk (Kelly & Brown, 2003; Rowell & Ebbers, 2004). Other studies focus on specific language forms of science such as argumentation (Brown & Renshaw, 2000; Duschl & Osborne, 2002; Jiménez-Alexandre & Erduran, 2008; Varelas et al., 2007). Argumentation is an essential scientific communicative skill used to challenge the findings of a community of practice in order to verify new scientific ideas (Carlsen, 2007). Further studies have examined the important role literacy, in particular, reading (see for example, Fang, 2006), and writing (see for example, Butler & Nesbit, 2008; Chen, Hand & McDowell, 2013) play in linking language and reasoning in science.

Another perspective explores language and identity within the classroom. These studies mainly focus on marginalized student populations who have English as a Second Language or are socio-economically disadvantaged (Huerta, Irby, Lara-Alecio & Tong, 2015; Stoddard, Pinal, Latzke & Canaday, 2002). Earlier studies have shown how science achievement is affected by linguistic differences (Lee & Fradd, 1996, 1998), whereas more recent studies argue the engagement in scientific language can be viewed as "a cultural conflict for marginalized students" (Brown, 2006, p. 96).

A further perspective takes a multimodal perspective towards language (Roth, 2005b; Siry, Ziegler, & Max, 2012; Taylor, 2014; Varelas et al., 2014). This approach downplays the dominance of oral language in communication and considers the impact of physiological actions such as voice inflexion, gestural expressions, body postures, and technical artifacts, for example literacy texts, writing and drawing implements, and computer programmes (Roth, 2008; Taylor, 2014). Analysis of the language in the science classroom can therefore include a variety of, "linguistic, visual, spatial and haptic" modes (Taylor, 2014, p. 404).

As this present study focuses specifically on the students' use of spoken scientific language, the remainder of this review will concentrate on the research literature examining students' oral language within the science classroom. This involves: research related to students' understanding of the meaning of scientific terminology; the research debate regarding students' use of everyday and scientific language; the literature focusing on language and the meaning-making process in the science classroom; and studies focusing on the pedagogical implications for teaching scientific language.

A series of studies in the latter part of the twentieth century examined students' understanding of the meaning of specific words used in science (see Cassels & Johnstone, 1985; Marshall, Gilmour & Lewis, 1991; Meyerson, Ford, Jones, & Ward, 1991; Pickersgill & Lock, 1991). These large scale studies, involving students from Australia, Phillipines, Papua New Guinea, America and United Kingdom, showed misconceptions and confusions in students' understanding of the meaning of some technical and non-technical science vocabulary. It was particularly noticeable with words that had more than one meaning or a different meaning from everyday language usage, for example 'mass' and 'organ'. These findings are consistent with the results from New Zealand studies, such as the early research reports of the Learning in Science Project (Osborne & Freyburg, 1985) and a smaller study conducted by Milne (2001).

The results from Cassels and Johnstone's (1985) research study revealed in "a surprising number of cases pupils take the opposite meaning to that intended: negligible = a lot; initial = final; random = well ordered" (p. 14). Later studies demonstrated similar results where a number of students substituted the antonym for the synonym (Marshall et al., 1991; Pickersgill & Lock, 1991). Furthermore, students showed confusions between words that looked and sounded the same e.g. detect and protect (Marshall et al., 1991). Studies of logical connectives used in science showed similarly concerning results with student's lack of understanding of linking words and phrases used (Byrne, Johnstone & Pope, 1994).

These research studies used predominantly written multiple-choice tests in different formats to examine students' knowledge of scientific words in context which enabled the researchers to survey large samples of the student population ranging from 197 students (Pickersgill & Lock, 1991) through to over 2000 students (Marshall et al., 1991). This methodological approach can be regarded as a momentary snapshot of students' understanding of the science vocabulary thereby treating scientific language as a static phenomenon, devoid of an authentic, meaningful context. Whilst acknowledging these limitations, it is possible that although students may use scientific language and give the appearance of understanding the meaning of these scientific words, it is not until they are in a situation of having to demonstrate knowledge of the precise meaning of these words that there are indications of confusions and misunderstandings. This shows that although the students' phonetic and syntactical knowledge can assist them in using scientific vocabulary, it does not necessarily mean the students have the necessary semantic knowledge to understand the meaning of the science words they are using. Consequently, students' use of scientific language does not necessarily indicate they understand the meaning of specific science vocabulary (Skamp, 2015; Wenham, 2005; Wellington & Osborne, 2001). This leads to the consideration of how and when students should master the correct scientific terminology.

There is much debate within the research literature regarding students' use of everyday and scientific language (Ash, 2008; Roth, 2005b; Varelas et al., 2007). Some researchers consider students must learn and use scientific language, including the technical vocabulary and the appropriate linguistic features, in order to demonstrate their understanding of the scientific concepts, and to communicate their thoughts and ideas about the world around them (Halliday & Martin, 1993). Gee (2004) views the "lifeworld language" (p. 16) used by students in their everyday life as totally different from the language used in the learning of science. He argues this everyday language, whilst appropriate for communicating aspects of the human experience, can constitute a liability in the learning of science. He explains, "from the perspective of scientific Discourse, it [lifeworld language] can create a symmetry that is misleading and obscures important underlying differences" (p. 27), and systematic patterns essential for scientific thought. Gee emphasizes the importance of students using scientific terminology alongside scientific activities. Rather than using everyday language in the science classroom, Gee advocates the explicit teaching of the specialized vocabulary and grammatical features of scientific language in conjunction with scientific activities, even for younger children. Proponents of this view consider students who continue to use everyday language within scientific contexts, may experience difficulty adjusting to the vocabulary and linguistic practices embedded in scientific language (Ballenger, 1997; Delpit, 1988; Gee, 2005).

In contrast, other researchers (Lemke, 1993; Roth, 2005b; Varelas et al., 2006; Wallace, 2004) argue students need to use their everyday language first in order to use and understand scientific ways of using words. Therefore, everyday language is to be considered an asset in the classroom as opposed to a liability (Varelas et al., 2007). Roth (2005b) describes students' developing use of scientific language as evolving or emerging, dependent on the students' prior experience, home culture, own language and knowledge. He uses the analogy of exploring a darkened room to explain the process students go through in order to make sense of an unfamiliar scientific phenomenon. It is through actively engaging in discovering anything and everything about the room that one begins to attempt to explain the room's layout. As one becomes more familiar with the room, vague descriptions become clearer through more precise vocabulary. It follows that in the scientific context, the students' language and knowledge interact and develop together as the students engage with the phenomenon.

This perspective views students' use of scientific language as a process that begins with everyday language (Lemke, 1993). When conceptual understandings and linguistic registers of the scientific world encounter the students' everyday thinking and language, students may begin to supplement their everyday language with technical scientific terms. Various terms for this version of scientific language include interlanguage (Lemke, 1993), double talk (Brown & Spang, 2008), hybridization of students' scientific and home languages (Roth, 2014), and hybridity (Varelas et al., 2006). This hybrid mode of everyday and scientific talk involves, "a mixture of two social languages within the limits of one utterance, an encounter, within the arena of an utterance, between two different linguistic consciousnesses, separated from one another by an epoch, a social consciousness or some other factor" (Bakhtin, 1981, p. 89). Students use everyday and scientific language when they are cognitively ready. In other words, students' choice of the language is dependent on students' level of conceptual understanding.

The next stage is referred to as the third space where the language and thinking of the scientific and the everyday world inform one another, resulting in the construction of new knowledge and understandings (Wallace, 2004). It is the integration of both languages with understanding that leads to the students eventually using fully scientific language, sometimes referred to as “speaking pure science” (Lemke, 1993, p. 173). The students do not necessarily transition between these stages in a purely linear fashion, but move back and forth, “between the ways they know the world and the ways others know the world” (Moje, Ciechanowski, Krammer, Ellis, Carrillo & Collazo, 2004, p. 44). Therefore students’ use of scientific language will not necessarily indicate an understanding of the meaning of the vocabulary, or the concept under discussion (Skamp, 2015; Wenham, 2005; Wellington & Osborne, 2001), but it does indicate the process students are engaged in as they develop their ability to articulate, through spoken language, their thoughts and ideas about the world.

The students’ use of everyday language as “intellectual resources” (Warren et al., 2001, p. 548) has been the focus of numerous studies (Ballenger, 1997; Warren et al., 2001; Southerland, Kittleson, Settage & Lanier, 2005). Other studies have explored how students use everyday language as the initial step for students to engage in scientific meaning-making (Brown & Spang, 2008; Roth, 2005b; Scott, Mortimer & Aguiar, 2006). This perspective contrasts with Gee’s (2004) view of the use of everyday language in meaning-making within the classroom science context as a liability or an inferior form of thinking.

Some researchers perceive students’ use of everyday language as the rejection of the perceived normalization of scientific discourse in order to preserve their cultural identity (Arnold, 2010; Brown, 2006). Cultural identity in this respect does not necessarily refer to students’ ethnicity but more so to students’ prior experiences, and how they use these experiences to order their world in their own words. Students’ meaning-making practices are situated within, and therefore are influenced by, their own histories from their home and school experiences (Gutierrez & Rogoff, 2003). As a result, students often prefer to use their own ways with words to make sense of their world.

This can be observed in children when they describe their observations using their everyday language and may not necessarily immediately adopt the teacher’s contribution of the correct scientific terminology into their linguistic repertoire. To illustrate, children often use everyday language such as ‘melts,’ ‘disappears’ or ‘breaks up’ when describing the dissolution of jelly crystals (Ng, 2010). This is not indicative of solely younger children’s thinking and reasoning. Older secondary school children often use these terms in relation to dissolution (Çalık, 2005). It indicates that they have observed a change in the solute at the macroscopic level. However, their conceptual understanding of dissolution is still fragmented, without the strong connections to enable the students to discriminate between the processes of melting, disappearing and dissolving (Çalık, 2005). Hence, the children do not necessarily switch to the scientific language even when the teacher uses modeling and scaffolding strategies to encourage the use of the term ‘dissolves.’ Instead, they may use their “emergent language forms” (Varelas et al., 2001, p. 28) as their scientific understanding develops, only adopting the scientific language when they are cognitively ready.

In the 1980s and 1990s, there emerged a trend for teachers to substitute everyday words for scientific terminology (Maskill, 1988). This approach recognized the complexity of scientific concepts and viewed the simplification of the language as a means for the students to gain mastery of these concepts. However, this approach does not necessarily incorporate the view that scientific language and scientific conceptual development are essentially intertwined (Arons, 1983; Vygotsky, 1981; Wellington & Osborne, 2001). The importance of conceptual understanding for scientific terminology usage lies in the acknowledgement:

> that to be understood and correctly used, such terms required careful operational definition, rooted in shared experience and in simpler words previously defined; to comprehend, in other words, that a scientific concept involves an idea first and a name afterward, and that understanding does not reside in the technical terms themselves (Arons, 1983, p. 92).

Learning to use the language of science within meaningful contexts is essential for learning science. Vygotsky (1981) in his seminal work, *Language and Thought,* emphasized that language and thought are inextricably interdependent. By using words, students are helped in developing their conceptual understanding. Conversely, "the understanding of science concepts is tied up in words, with which we define, explain, build models and employ metaphor to convey our current thinking about the world around us" (Dawes, 2004, p. 679).

The social context can have a major influence on scientific language. The social aspects of language and science education are highlighted in the work by Lemke (1990). His book, *Talking Science, Language and Values,* is regarded as significant in language studies in science education (Kelly, 2007). Lemke viewed the teaching and learning of science as involving human actions within the socially constructed context of the classroom. These actions include student-student/s and/or student/s-teacher dialogues, including those occurring whilst engaged in physical activities related to the scientific phenomenon. Scientific meaning-making is viewed as socially negotiated through language over time between collaborating group members. For all intents and purposes, scientific knowledge is talked into being within the social context (Bakhtin, 1981; Gallas, 1995; Lemke, 1990; Roth, 2005b; Siry et al., 2012). Language and thought are inextricably intertwined with the ideas that emerge within the social context of whole class or small group before they are assimilated into the realm of the individual student's thinking and reasoning (Vygotsky, 1981).

Research studies have examined the pedagogical implications for teaching scientific language. There are two schools of thought regarding the type of support teachers need to provide in order to promote the students' use of scientific language. Some science educators regard the teachers' role as providing explicit instruction to support students towards a structured and stylized form of scientific language as found in school scientific textbooks (Lee & Fradd, 1996). Other science educators, however, consider it is important not to repress students' creative, spontaneous, and at times, changeable thought processes, articulated in everyday language which they consider indicative of real-life scientists ways of working and thinking (Gopnik, 2012; Hudicourt-Barnes, 2003, Roth, 2005b). Lee (2005) suggests combining both approaches. This means the teacher would acknowledge and accept students' everyday language and thinking as well as explicitly teaching the vocabulary and discursive features of scientific language.

Some researchers recommend the explicit teaching of scientific language similar to second language teaching and learning (Brown & Spang, 2008; Wellington & Osborne, 2001). In their book, *Language and Literacy in Science Education,* Wellington and Osborne (2001) not only present the research findings in the scientific language area, but also practical ways, such as activities and games, the classroom teacher can utilize to supplement their science programme to assist students in understanding and practising using scientific language.

Many researchers caution using scientific vocabulary, especially technical terms, with younger students, as they consider this may lead to a superficial usage that could mask students' conceptual misconceptions (Hipkins et al., 2002; Wellington & Osborne, 2001). They identify explicit teaching, through models, analogues and scientific inquiry, to develop students' conceptual understanding before the introduction of specialist vocabulary and the grammatical language features. In other words "meaning has to be taught, not caught" (Wellington & Osborne, 2001, p. 19) in a "content-first approach to science" (Brown & Ryoo, 2008, p. 529).

Further research studies have emphasized the role of the teacher in providing appropriate support to enable students to successfully transition from everyday language to scientific language (Brown & Ryoo, 2008; Brown & Spang, 2007; Rowell & Ebbers, 2004; Warren et al., 2001). The importance of teacher scaffolding in order to move the students from the use of everyday language towards a language of scientific inquiry where students critically scrutinized their observations as a way to generate or confirm scientific knowledge was emphasised in a study of grade 6 Canadian students' language during an inquiry-based unit (Rowell & Ebbers, 2004). Teacher modeling of scientific language was the focus of an ethnographic study by Brown and Spang (2008), which examined the impact of explicit teaching of scientific language to a class of 27 grade 5 African-American students over an eight-month period. The classroom teacher modeled the acquisition of scientific language by using both everyday and scientific terminology in her explanations and discussions of scientific concepts. The results showed the students adopted this hybrid form of scientific and everyday talk, or "double-talk" (Brown & Spang, 2008, p.708). Although highlighting the small research sample and the lack of a control group for comparison, the authors concluded the results demonstrated the importance of explicitly teaching the language of science within an environment that supports the emerging use of scientific language along with developing scientific understandings.

There are also studies examining the way teachers can organise the social setting within the science classroom to promote the use of language. Lemke (1990) claims "learning science means learning to talk science" (p. 1) which entails students having multiple opportunities to talk in order to make the language of science their own. His research of school science classroom discourse revealed a dominance of teacher talk with limited opportunity for students to participate. Science lessons often involved a three-way dialogue whereby the teacher asked a question, and then solicited and provided feedback to a student contribution. This resulted in a classroom culture where the "acceptable ways of talking science are tightly controlled" (Kelly, 2007, p. 445) by the teacher.

Recent studies indicate a more focused approach to using group and class discussions to encourage students' use of language. These discussions can consist of either student-student/s or student/s-teacher dialogue. There is an increasing use of group work in science classrooms as a pedagogical strategy to increase student motivation and involvement (Bennett et al., 2010). Moreover, group work can provide students the opportunity to use language as they make observations and generate explanations. Within this setting, students have the opportunity to construct knowledge through the collaborative sharing, shaping and refining of each other's ideas. In contrast, whole classroom discussions involve the teacher with the students and generally focus on clarifying explanations and justifying ideas (Anderson, Thomas, & Nashon, 2008; Tytler & Aranda, 2015; Woodruff & Meyer, 1997).

2.4.4 Evaluation of the Literature - What research is missing?

It has been shown that there is considerable research literature in relation to students' use of scientific language from the early primary school level (Brown & Spang, 2008; Southerland et al., 2004; Varelas et al., 2006), through to the secondary school level (Roth, 2005b; Scott et al., 2007). However, there are calls to use more specific discourse approaches to analyze scientific language data (Bennett et al., 2010; Carlsen, 2007). Discourse analysis (see 3.4.4.2 for definition) has been used in groupings that have included the teacher and the students (Brown & Spang, 2008; Tytler & Aranda, 2015), but as far as I know there is no research literature utilizing discourse analysis that focuses on scientific language used by students in small group discussions, with no teacher present. This present study will attempt to address this gap in the literature by using discourse analysis for the data gathered from small group discussions.

Research has generally involved whole class or small group discussions, with the teacher present and interacting with the students. Crawford, Kelly and Brown (2000) highlight the "need for studies of science in various settings and interactional contexts" (p. 241) when examining students' scientific language usage and understanding. This study acknowledges this point and explores students' scientific language within two different social contexts and interactional formats. First, the students discussed their science knowledge within an interview setting where the teacher/researcher had a predominantly listening role. Second, the students engaged in meaning-making during small group science activities where the teacher/researcher was not present. This second context, in particular, provided an opportunity to observe the students' language use as they articulated their creative, spontaneous, and at times, changeable thought processes whilst engaged in collaboratively constructing collective scientific knowledge and understandings. This follows the Vygotskian stance that scientific language emerges within social contexts before becoming part of the individual student's way of talking. The findings revealed the processes the students experienced as they developed their ability to use language to convey the way they see the world around them and as a result highlighted pedagogical implications.

The majority of studies on scientific language have focused on urban students from larger schools, often from one class level. There is no literature that examines students' scientific language in rural primary schools, in particular, very small rural schools in New Zealand. This research will fill this gap by situating this study within a two-teacher, multi-level class in a very small rural New Zealand school.

2.5 Conclusion

This research study examines the influence of the Chemistry Outreach programme on rural primary school science students' attitude towards school science, engagement with school science, and the use of scientific skills and language. Examination of the current research relating to these aspects of science education has revealed two major gaps in the science education literature base.

First, most of the science education literature has concentrated on single-level classes within urban schools, resulting in no research examining science students within the context of a very small rural primary school, in particular for this present study a New Zealand two-teacher school. As explained earlier (see 1.1.5), very small rural schools in New Zealand have a unique organisation, generally one teaching principal and one other teacher, resulting in multi-level classes with an age range from four to eight years, depending if it is a one or two-teacher school, and therefore, the strong possibility of students having one or more siblings in their class.

Second, while existing literature has revealed themes and issues regarding aspects of primary school science students' attitudes towards school science, engagement with school science, use of scientific skills, or use of scientific language, to the best of this researcher's knowledge, there is no research that has examined all these concepts within the one study. This study will endeavour to bring all these aspects together in order to present more of a holistic picture of these students and their experience of the Chemistry Outreach programme. As far as I am aware, there has been only one article published on the affect of the Chemistry Outreach programme on primary school students, however these students were from urban schools (Bolstad & Bull, 2013).

This study takes a phenomenological view of teaching and learning as involving “hand (acting), heart (feeling), and head (thinking)” (Henriksson & Friesen, 2012, p.9). Therefore, this research provides a unique opportunity to explore primary rural school science from the perspective of the students’ heart (attitude), hands (engagement) and head (scientific skills and language) thereby providing a rich, in-depth, more holistic view of science learning for these rural school students. This will come from the students as they talk about and within science thereby addressing the lack of student voice in small rural schools’ research (Hargreaves, 2009; Rudduck & Flutter, 2004). As phenomenology is a “relatively seamless way of seeing pedagogy” (Henriksson & Friesen, 2012, p. 9), the results of this study will inform pedagogical implications that focus on more of a holistic view of teaching and learning involving the heart, hands and head. The discussion now turns in Chapter Three to the research methodology and details of the different stages of the research process, including data gathering and analysis, used in order to achieve the research purpose.

CHAPTER THREE
METHODOLOGY

3.0 Introduction

The purpose of this study is to investigate very small rural primary school students' experiences of a science initiative with a specific focus on students' attitudes, engagement, use of scientific skills, as well as scientific language. The overall research design has been influenced by the research questions and the phenomenon under study, which is a science initiative programme, and the way it is experienced by the students. This study is framed by the qualitative research paradigm and uses phenomenology methodology. Data are analysed at an individual and social level using phenomenological analysis and discourse analysis.

This chapter outlines the theoretical framework used in this study and details of the different stages of the research process. The chapter continues with the clarification of the researcher's position and then a description of the methods employed in the research process, including the selection of participants and data gathering methods. Insights into the methods of data analysis used, namely phenomenological analysis and discourse analysis are provided. Finally, ethical considerations are discussed including informed consent, power relations, and confidentiality. As this research focuses specifically on children aged eight to eleven years old, there is particular attention shown to the methods used to conduct research involving children.

3.1 Research paradigm

Research paradigms are world views or belief systems, and these ways of understanding and thinking influence the manner in which researchers approach and conduct their research (Guba & Lincoln, 2005). The philosophical underpinnings of paradigms are centred on specific views of reality (ontology), and knowledge (epistemology), that influence the decisions researchers make regarding ways of finding out this knowledge (methodology). This study adopts the ontological position of relativism and is therefore framed by the qualitative (interpretive) paradigm. Relativism views knowledge as individually constructed thereby resulting in multiple interpretations of reality (Guba & Lincoln, 2005; Crotty, 1998). Language plays a vital role as reality evolves and is shaped through individuals interactions between language and the world (Frowe, 2001). The epistemological stance taken by this study supports the perspective of knowledge as subjective. Although knowledge is constructed by individuals in many different ways "truth is a consensus formed by co-constructors" (Pring, 2000, p. 251). Knowledge is culturally and historically situated and socially created. That is to say, it is constructed through interactions between individuals and their world, and communicated within a social context (Crotty, 1998). This social world becomes their world, interpreted by them, and therefore "can only be understood from the standpoint of the individuals who are participating in it" (Cohen, Manion & Morrison, 2007, p. 19).

3.1.1 Qualitative research

Qualitative research endeavours "to make sense of, or interpret, phenomena in terms of the meanings people bring to them" (Denzin & Lincoln, 2011, p. 3). Therefore, the aim of the qualitative paradigm is to understand as opposed to generalise (scientific paradigm) or to emancipate (critical paradigm). The qualitative research paradigm is considered appropriate for this study as the purpose is to understand the meaning of the experience of science for rural school students within the context of the Chemistry Outreach science programme and situated within their own rural culture.

This study fits in with the limited but growing literature on science education set within the qualitative approach (Bennett & Hogarth, 2009; Lyons, 2006). Although quantitative research has the advantage of generalizability of the findings, often this approach is conducted through research methods such as Likert-type surveys, which can tend to restrict the focus of students' answers towards predetermined categories (Lyons, 2006). On the other hand, qualitative research does not limit the focus of the students' answers, but offers the opportunity to study the students' experience of science through the students' perspective and within the context of its use. This provides the opportunity to explore meanings and explanations to arrive at a deeper and richer understanding of the students' experience of science (Lyons, 2006; Osborne et al., 2003).

3.1.2 Phenomenological methodology

Qualitative research is an overarching term that embraces an extensive range of complex, evolving methodologies and research practices of which phenomenology is one (Punch, 2005). Phenomenology is both a philosophy and a research method that is focused on gaining a deeper understanding of the participants' lived experiences, by revealing how and what the participants experienced (Creswell, 2013; Crotty, 1996). Phenomenological inquiry is regarded as important in the field of educational research as it views education from the students' perspective (Vandenberg, 2002). Often referred to as a lived experience human science inquiry approach (Henriksson & Friesen, 2012), phenomenology has been used with a specific education/pedagogical focus (van Manen, 2007) and to a limited extent in the area of science education (Ostergaard, Dahlin & Hugo, 2008).

This study is framed by the overarching phenomenological question of what is the nature of this phenomenon (Chemistry Outreach science programme) as an essential lived experience through the perspective of primary school students from a very small rural school. Therefore, from a phenomenological point of view, the focus is not on asking "How do these children learn science?" but on asking "What is the nature or essence of very small rural primary school students' experiences of learning science through the Chemistry Outreach programme?" in order to better understand what this particular learning experience is like for these children.

Phenomenology was selected as an appropriate methodology to use for the purposes of this study for five reasons. First, phenomenology is more than just describing the lived experience. It allows for the inclusion of multiple interpretations of reality, which is important as students experience learning in different ways. Second, phenomenology focuses on the meaning of the experience from the participants' perspective. For the present study, phenomenology is used to understand the lived experiences of science through the students' talking in and about the Chemistry Outreach programme. Third, phenomenology further enhances the "deeper understanding of lived experiences by exposing taken-for-granted assumptions about these ways of knowing" (Starks &Trinidad, 2007, p. 1373). In relation to the present study, this implies that the focus is on the students' direct experience of the Chemistry Outreach programme, and therefore, any preconceptions I had about the students' previous experiences with school science and connections with applied science within their farm home life are put aside. Fourth, phenomenological research implies a moral responsibility to understand students' learning in order to inform the use of appropriate and effective pedagogical strategies (Dall'Alba, 2009). This study seeks to understand students' experiences of school science within the socio-historical context of a very small rural primary school located a small rural community in order to ensure the successful pedagogical support for their learning and development. The present study is informed by van Manen's (1990) approach to phenomenological inquiry, variously referred to as Phenomenology of Pedagogy or Human Science for an Action Pedagogy. Although Interpretative Phenomenological Analysis (IPA) and Phenomenology of Pedagogy both draw on the theories of phenomenology and hermeneutics, IPA focuses more on the field of psychology whereas Phenomenology of Pedagogy concentrates on orientating oneself to human experience within the educational context (Frost, 2011). The use of Phenomenology of Pedagogy better addressed the research study of rural primary school students' experiences of the Chemistry Outreach programme. Finally, phenomenology perceives pedagogy as encompassing the "hand (acting), the heart (feelings) and head (thinking)" Hendriksson & Friesen, 2012, p. 8). This study will examine the affective domain (feelings) to reveal students' attitudes towards science, the behavioural view (acting) to indicate engagement with science, and the cognitive perspective (thinking) to reveal the students' use of scientific skills and language. This will hopefully present more of the wholeness of these students' experiences of learning science.

3.1.3 Culturally responsive pedagogy

Ladson-Billings (1995a, 1995b) was the first scholar to coin the term 'culturally responsive pedagogy' to refer to the mismatch between the home-community and school teaching styles, especially for racial/ethnic minority students. Culturally responsive pedagogy is perceived as a way to address the effects of the achievement gap between minority and mainstream students, and often focuses on preparing teachers to teach students from different cultural backgrounds to their own (Gay, 2000). This type of pedagogy is where teachers, "acknowledge the home-community culture of the students, and through sensitivity to cultural nuances integrate these cultural experiences, values, and understanding into the teaching and learning environment" (Brown-Jeffry & Cooper, 2011, p. 67). This means the students' cultural knowledge is not regarded as a barrier to learning but becomes part of the authorized or official knowledge within the classroom setting (Ladson-Billings, 1995b).

In this present study the rural context is not regarded as simply a geographical term but rather is viewed as a unique culture specific to this particular community (Anderson & Lonsdale, 2014). Furthermore, this culture is positioned within the macro-culture of Aotearoa New Zealand, a bicultural society that acknowledges the cultures of the indigenous Māori as well as the European settlers. Culturally responsive pedagogy in New Zealand generally focuses on ethnic minorities or marginalized cultures (for example, Māori or Pasifika students), in order to make learning meaningful and engaging in an attempt to lift student achievement (Bishop & Berryman, 2009; Glynn, Cowie, Otrel-Cass & MacFarlane, 2010; McKinley, 2005). In this study, the students belong to a Eurocentric middle class socioeconomic group. This study takes the perspective that these rural school students are entitled to learn as rural school students, where meaningful and authentic connections are made between their distinctive home-community culture, and the school culture. The findings of this study are discussed in relation to the students' rural culture by using the culturally responsive pedagogy framework espoused in *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011).

3.2 Educational research in rural settings

As already stated, this research is situated firmly within the rural context, examining nine rural primary school students' experiences of science. It is important that researching from the rural standpoint "is more than a setting for research or a point of difference justifying publication" (Roberts, 2014, p. 280). Such research is at risk of contributing little to the understanding of rural life and experiences. I acknowledge that my research involves science education in the rural context, which is an area that is under researched in New Zealand as shown in the literature review. Furthermore, I acknowledge that I was a teaching principal of a rural school throughout the duration of this research study. However, choosing to locate this research within a rural setting was not because of convenience, but more a deliberate decision. I approach this research from the view that rural schooling, rural education, and rural communities are an important part of New Zealand's educational and national scene, and as such they really do matter. Therefore, it is important to me that this particular experience of science, the Chemistry Outreach programme, as experienced by rural students within a rural school, is understood in-depth.

This research is not about presenting rural education as being disadvantaged, marginalised, or highlighting aspects of injustice or inequality. Moreover, this research is not about dichotomizing or comparing rural and urban education. This research is about acknowledging the intrinsic significance of rural places and rural life to the rural student in their science education. There is no intention to generalise the findings to other rural schools, as there is a huge diversity in the makeup of rural schools in New Zealand. This research is specifically situated within the context of a very small rural primary school, and needs to be considered within that context. However, it is hoped that this research will be able to speak to the rural as well as the urban in the respect of acknowledging the importance of students' home background, culture, and prior experiences.

3.3 Chemistry Outreach programme

As already stated, the Chemistry Outreach programme studied here is the result of a partnership between the University of Otago Chemistry Department's Outreach programme and the rural primary school where I was a teaching principal. The following description of the programme is presented in table form in Appendix A. Phase 1 of the programme, which consisted of 6 visits from the Chemistry Outreach team over the period from September 2011 until December 2011, involved sessions that were designed to focus on the 'wow' factor in science. The aim was to engage and motivate the children in a variety of demonstration and hands-on activities. The scientists demonstrated a range of experiments to show changes in the three states of matter by using liquid nitrogen and dry ice. For example, liquid nitrogen was used to freeze everyday objects such as rubber tubing, mandarins and onions, whereas dry ice was placed inside a balloon to inflate the balloon. To conclude phase 1, there was a series of activities which introduced the students to measuring accurately, reporting their observations, and the idea of replication.

After the introductory sessions, Dr Dave Warren, the Outreach team, and I discussed ways "to make science relevant, useful, and meaningful for these rural students, and to create strong connections between them, the science, and their world" (Penrice & Sexton, 2013, p. 59). The possibility of developing a unit on water and soil testing, in particular pH testing, was deemed appropriate and relevant as all the students were aware of these types of testing in their everyday life. During the summer months, the Year 6 senior students' responsibilities included testing the swimming pool water each morning with the school's pool attendant. Furthermore, one family's mother was the pool attendant at the neighbouring town's pool and the children had observed her testing the water. The children were aware that testing of the swimming pool water was done to ensure their safety to swim. Many students had observed the testing for soil pH and nutrients on their farm before fertiliser application as part of usual farm practice. The students recognised the importance of water and soil quality for animal health on the farms where they lived. Although the students had experienced water and soil testing, they had a limited understanding of what the process entailed and why.

The second phase involved 6 visits from February until May 2012. The focus was on pH activities undertaken by the students with a partner. The aim was to be more hands-on during the science sessions with the students involved in the preparation, planning, and doing of the activities.The scaffolded learning experiences involved making natural pH indicator by extracting anthocyanin (the red, blue or purple colour pigment of plants) from red cabbage and using this to test the pH of common items such as vinegar, baking soda, milk and lemon juice. The students compared the results to the pH scale and discussed the safety of these liquids in relation to the acidic or alkalinity readings. After reading *Green Eggs and Ham* by Dr Seuss the students created green eggs by adding the red cabbage indicator to the egg white. They then tested the food in their lunch boxes. Using both the red cabbage indicator and universal pH indicator the students tested water samples gathered from the school and community environment incuding water from the swimming pool, a pond, the local river, a water trough, farm stream, and a goldfish pond. Soil samples were collected from various paddocks on a nearby farm and these were also pH tested. The results of the water and soil tests were collated and compared.

The third phase, five sessions from July to September 2012, involved the students using their newly acquired skills of water and soil pH testing to plan, design, conduct, and evaluate scientific investigations in their community. The aim was for the students to apply their skills and knowledge in a meaningful context that would have relevance for them, their families, and the local rural community. The first group investigated the effect of cowpats on the pH and nitrates of the soil; the second group explored whether the pH of the water changes with the depth of the water, and if the bugs in the water changes the pH of the water; while the third group studied the difference in the pH between surface and bottom pond water and whether the depth of water changed how plants grew. Students presented a summary of their research process, including the analysis of the data, to the local community at the end of year community assembly (Orr, 2013; Penrice & Sexton, 2012).

3.4 The research process

This section clarifies my position as researcher. It then proceeds to describe the methods employed in this research. This study involves research with children. The way researchers view children and childhood influences the researcher's role, methods used, and the interpretation and presentation of the data to gain an accurate understanding of children's experience within the specific contest within which it takes place (Graham & Fitzgerald 2010; Powell & Smith, 2006). Researchers need to critically reflect throughout the research process (Einarsdóttir, 2007; Goodenough, Williamson, Kent & Ashcroft, 2003; Kirk, 2007; Sligo 2001) to ensure that the children's voices are being heard rather than being perceived "through the lens of adultist assumptions" (Hendrick, 2008, p. 58). I have gone into some depth about the approach taken with the children with regard to data gathering, especially in relation to informed consent, power relations and confidentiality

3.4.1 Researcher position

Within this study, I am aware that I have a multiplicity of positions in relation to the participants. I am a rural primary school principal, an experienced primary school teacher, a collaborator with the Outreach Science team, as well as this study's researcher. The research took place in the school where I was principal. Through these multiple roles I bring my own "histories of participation" (Rogers, Malancharuvil-Berkes, Mosley, Hui & O'Garra, 2005, p. 382) to the institution where this research takes place. Although I could have been considered an outsider from a research perspective due to not having resided within the researched rural setting, I did have insider information from working in the researched school, and living on a farm in a nearby rural area. It could be argued that this common background of experiences "can easily block perception" (Strauss & Corbin, 1998, p. 47). However, an insider researcher stance can also have advantages for the researcher's access and immersion into the research context. As both researcher and teacher of the students who were participating in the science initiative, the informal approach of "I" for the researcher is used at times throughout this study. I had previously experienced Chemistry Outreach at a larger urban school, but as a phenomenological researcher I need to 'bracket' these experiences in order to understand those of the students in the study. Bracketing involves the researcher describing and setting aside prior experiences and understandings of the phenomenon under investigation before examining the phenomenon from the participants' viewpoint. The use of bracketing ensures validity or objectivity of the interpretation against self-interest (Laverty, 2003).

My prior experiences of the Chemistry Outreach programme were of one or two sessions a term where the teacher in charge of science organized the programme so the content aligned with the school-wide inquiry themes. The extent to which one can put aside past knowledge of the phenomenon under investigation is questionable, as the research process requires a degree of close involvement (Finlay, 2008). To ensure my prior experiences did not unduly impact on the current study, I abstained from making any comparisons with my knowledge of the Chemistry Outreach programme and the present study. Furthermore, in an attempt to maintain researcher objectivity any conclusions drawn from the study were based on data with an indication of how these conclusions are arrived at, for example, referenced quotes from interviews or an audit trail where themes can be related back to the original data source. This links in with the concept of reflexivity which is "an awareness of the ways in which the researcher has devised the research question, elicited and gathered the data, analysed it and then presented the research to a wider audience (Frost, 2011, p.195). Phenomenological studies "aim at elucidating lived experience …[as] the meaning of lived experience is usually hidden or veiled" (van Manen, 1990, p.27). Therefore, it is necessary to be explicit about the research design so an "understanding of how interpretations of the data were reached" (Frost, 2011, p.195). This is addressed in the next section on the research design.

3.4.2 Selection of participants

The selection of participants was aimed at describing the essence of the phenomena by gaining "insights and in-depth understanding rather than empirical generalizations" (Patton, 2002, p. 230). The selection was dictated by the phenomenon, and therefore involved identifying and locating participants who were going to experience the Chemistry Outreach programme. The sample size was dictated by the research design as phenomenological inquiry seeks a deep understanding of individual's experiences. In this respect, all the students in the class involved in the Chemistry Outreach programme were selected as the total number at the start of the initiative was only 11 students. Through the consent form (see Appendix G), the participants were advised they could withdraw at any stage without any disadvantage to themselves or others participating in the programme. The objective was to give each of these participants a voice, but it must be noted that these participants are not to be taken as representative of other New Zealand rural school communities.

3.4.2.1 Selection of student participants

All the students in the class where the Chemistry Outreach programme was going to take place were offered an opportunity to participate in this research. Originally all eleven students (the total number in the class) gave their consent, but over the duration of the programme two students left for other schools. Therefore their data was destroyed as promised in the consent form and not used in the final research report. The remaining nine students were involved in this study. They attended a Year 1 - 6 rural two teacher primary school located in a well-established South Island sheep and beef farming area. These students, 6 boys and 3 girls, belonged to the Year 4 - 6 senior class. The class levels and pseudonyms are 3 boys at Year 6 (Tom, Jerry, Peter), 1 girl and 2 boys at Year 5 (Maree, John, Ken), and 2 girls and 1 boy at Year 4 (Lisa, Kelly, Shane). All the students lived on farms, as their parents were involved in the agricultural sector as farmers.

3.4.2.2 Selection of adult participants

This study also included the adult voices of the rural community in order to come to an understanding of the culture of this small rural community and the Chemistry Outreach progamme from an adult perspective. Adults included in this study were first, the parents of all the students at the school, and second, interested community members.

I approached a parent from each family either face-to-face or via a phone call to personally explain the research project and invite them to participate. Although participation was voluntary, all agreed to participate, thereby guaranteeing at least one adult representative from each of the families at the school. This equated to 18 parents from the total of 12 families at the school. This high rate of participation may be due to first, I was the new school principal and teacher of their children, and second, the perceived benefits of the science initiative programme for their children.

Criteria for inclusion as a participant for the community interviews included being a resident in the community and willing to comment on their perceptions of the community culture and their impressions of the Science Outreach programme. Participants for the community interviews were selected using a snowball sampling technique (Seale, 2005), whereby those already in the study had recommended others who met the preceding criteria (Bogdan & Biklen, 1998; Merkens, 2004; Morse & Richards, 2002; Patton, 2002). This proved to be a particularly effective method to recruit new participants as I was relatively new to the district and it provided an opportunity for me to contact people beyond my circle of acquaintances. Fourteen adults were contacted with all except one person agreeing to participate. This person was recommended by another participant based on the grounds she was a long term resident of the community. However, she found the whole idea of being interviewed somewhat overwhelming and thought that firstly, she would not have anything of any particular value to say and secondly, her health at that stage was not the best. She was given the option of being interviewed with other members of her family who were participating, but still declined.

3.4.3 Data gathering

Phenomenological inquiry is concerned with trying to understand what the experience is like from the participant's perspective. Therefore, data collection methods need to present the participant the opportunity "to offer a rich, detailed, first-person account of their experiences and the phenomenon" (Frost, 2011, p. 54). This approach means the researcher needs to allow enough time for good quality in-depth data to emerge (Bentz & Shapiro, 1998). The main sources for data in this study were semi-structured focus group interviews with the students and semi-structured one-to-one interviews with the adult participants. To add to the depth of this data, video recordings were taken of the students engaged in scientific activities to reveal their experiences within a social context. Furthermore, students' writing in the form of reflective writing and science book covers were used to reveal their personal attitudes towards the Chemistry Outreach programme.

The data collected focused on aspects of the four dimensions of attitude, engagement and the use of scientific skills and language. The aspect of attitude under investigation in the present study is based on the affective component of attitude, namely favourable or unfavourable feelings students have towards the Chemistry Outreach programme (see 2.1.1. and 4.1). Sources of data for attitude included three focus group interviews, reflective writing and the illustration of science book covers to establish any changes in attitude over time. The aspect of engagement being studied is the behavioural dimension of engagement which involved the students' participation, persistence, effort and/or attention in relation to school science within a group situation (see 2.2.1 and 4.2.1), and present engagement with the Chemistry Outreach programme (see 4.2.2.1.), and possible engagement in secondary school science (see 4.2.2.2). The science skills under investigation involved the language required for working and thinking scientifically when engaged in scientific investigations (see 2.3.1) from students' self-reports (5.1.1) and within a group science activity (5.1.2). The aspect of scientific language being studied focused on the labeling and interpretive functions of language in the science classroom with data gathered from student recounts (see 2.4.1.and 5.2.1), and working within a group science activity (see 5.2.2). To address concerns regarding the difficulty of correlating data with the behavioural dimensions of engagement, and the use of scientific skills and language, data consisted of both observable behaviour over time (videos of students participating in science activities), and reported data, that is focus group interviews.

3.4.3.1 Data gathering with students

As it was the intention of this study to gather in-depth information about the students' experience of a science initiative programme, three methods of data gathering were used: first, semi-structured focus group interviews; second, videos of the students involved in science activities; and third, students' written work in the form of reflective writing and science book covers (See Appendix B: Data Collection Schedule.) This data triangulation was used to assist in contrasting and validating data (Bloor, 1997; Holloway, 1997). The initial data gathering used all three of these methods to establish students' attitudes towards school science, while focus group interviews and videos were used for the exploration of students' engagement, scientific skills and scientific language. Written work involved students' science book covers the students completed during phase 2 and reflective writing at the end of the programme. The students were videoed doing science activities, once before the beginning of the programme and again during phase 3. There were three interviews with the students in small focus groups of up to six students prior to the commencement of the programme, and then at the mid-point, and after the year-long programme had finished. This longitudinal approach was used as a means to document any changes in their thinking and behaviours over time.

Seidman (2006) recommends a series of three interviews for in-depth phenomenological interviews, which is informed by life history interviewing (Bertaux, 1981) and the phenomenological writings of Schutz (1967). This approach enables a deeper understanding of the experience within the context of the lives of the participants (Seidman, 2006). Therefore, in this study, the first interview involved the students describing their prior experiences of science education programmes (see Appendix B: Data Collection Schedule). This gave the participants an opportunity to detail school science experiences within the context of their life history. In the second interview the students described their lived experiences of the Chemistry Outreach programme in detail. This focused on concrete examples of doing science at school, in other words placing their lived experiences within the context of the school setting. The third interview involved the students making sense of the experience for themselves by reflecting on the combination of past and present experiences of science. In essence, the participants had a chance to consider what they had said about their past and present experiences of science to reflect on what the Chemistry Outreach programe means to them (see Appendix C: Interview Schedule). The dimensions of attitude, engagement, scientific skills and language were explored through each of the focus group interviews. Specifically, attitude was explored in all three focus group interviews, while the use of scientific skills and language were revealed in the first and third focus group interviews, and finally, student perceptions of their long term engagement with science were examined in the third focus interview. The interviews ranged from 20 to 45 minutes with an average of 33 minutes. The length was determined by the interest, participation and concentration of the children during the interview session.

Video-based data are increasingly used in qualitative research as accurate and detailed records of classroom teaching and learning experiences (Fitzgerald, Hackling & Dawson, 2013). They offer the opportunity for close behavioural observations of the students within their lifeworld without the researcher being present or interacting with the students (van Manen, 1990; Wertz et al., 2011). In the present study, the videos of group science activities revealed the social interactions in science learning contexts experienced by the students in relation to the dimensions of engagement, skills, and language.

The first video took place prior to the beginning of the programme in order to document aspects of the dimensions under investigation before the students had experienced the programme. The students were involved in a group activity to design a fair test to find out if jelly crystals dissolve faster in hot or cold water (see Appendix D). This context was selected as the students had experienced jelly making in everyday life but had not been taught fair testing procedures. The second video recorded the students working as a group in an activity requiring the students to use an increasing amount of water with hydrochloric acid on magnesium tape (see Appendix E). The students were given written instructions and had to replicate three tests using three different concentrations of water and acid, for a total of nine tests. At the end, they had two questions to answer: What happened when you added more water? What is the water doing? This activity was chosen as the students had worked with the Chemistry Outreach team in the areas of accurate measuring, replication and reporting observations in phase 2. The students had not experienced the action of hydrochloric acid on magnesium tape so this activity gave the opportunity to observe any generalizations of these skills to this new experience. It was important both videos did not include contexts related to the programme as the focus was on examining the process the students undertook as they attempted to make sense of what they were seeing as opposed to recall of the content of prior learning experiences.

Written work offers the opportunity for children to record their ideas and feelings at their own stage of understanding and their own pace, adding details when and if they feel it is necessary (Kalvaitis & Monhardt, 2012). At the end of the programme, the students were asked to write their reflections on the Chemistry Outreach programme. Reflection in phenomenological inquiry "is not *introspective* but *retrospective"* (van Manen, 1990, p.10, original italics), as reflection involves experiences that are "already passed or lived through" (van Manen, 1990, p.10). The students were requested to write a description of their experience of the Chemistry Outreach programme as they had lived through it, as they had felt it. They were asked to focus on particular events or incidents that occurred during the programme that stood out for them. They were encouraged to try to describe how they were feeling and what was going through their mind during these events. Finally, they were assured that they did not have to worry about their spelling or trying to use fancy words.

Illustrating is another means of "giving shape to their lived experiences" (van Manen, 1990, p.74). During phase 2, the students were asked to decorate the covers of their Science Outreach books. These book covers were illustrated without teacher direction as no criteria were given, so the students could be spontaneous in their selection of drawing and any comments they used. The focus with the writing and illustrating activities was on the content, not the student's drawing or writing skills.

3.4.3.2 Data gathering with adults

Adults were interviewed either individually, or with their partner, depending on their choice. Ages ranged from the mid 20s to 50s for the parents, and from 40s to 70+ for community members. These interviews, which lasted approximately 40 minutes, were conducted either on the school grounds or a place of the participant's choosing, generally their home. The interview focus was on the adult's perceptions of the community's culture, and the participants were informed of the key questions in advance.

3.4.3.3 Recording interviews

Recording technology was used to allow the focus to be on the participants and the flow of the interview or observation, rather than the recording of the data. Micro-recorders were used as they can be less intrusive and therefore less inhibiting for the participants. This enabled the immediacy of the situation and the vividness of the speech to be captured. A second micro-recorder was used as a backup in case the primary source of recording failed (Easton, McComish & Greenberg, 2000). The technology was acknowledged at the beginning of the interview and I ensured that the participants were comfortable being recorded.

The children's initial focus group interviews were also video-taped as a visual guide to ensure that the transcription accurately recorded each child's contributions. The video camera was discretely mounted on a small pedestal some distance from the children. During the initial interview, I found some children were occasionally distracted by its presence. As it was important to ensure the spontaneity of all the children in the group (Litosseliti, 2003), I reverted to using only micro-cassette recorders to tape the remaining children's focus group interviews and observations. I found that as the group numbers were small and that I knew the children very well I was able to easily identify the speakers when transcribing. The video camera was not a distraction during the science activities as the students were engaged in what they were actually doing rather than looking at the camera.

3.4.3.4 Transcription

Transcription is an accurate graphic representation of conversational behaviours within the context of an interview or observation for the purpose of data analysis (Kowal & O'Connell, 2004). It is a necessary part of the research process to ensure quality data analysis as, "attempts at analysis without transcription will be prey to the dangers of selectivity and will also lose most of the richness of the data" (Bloor, Frankland, Thomas & Robson, 2001, p. 92). Documentation of the steps taken to ensure an accurate and trustworthy account is necessary "as an aspect of rigor in qualitative research" (Poland, 2001, p. 636).

All tapes of the interviews and observations were transcribed in full. I was particularly aware that attention needed to be given to the most accurate record of what the participants said, including accurate punctuation and spelling so that, "a greater degree of trustworthiness can be established, thus providing a high degree of methodological confidence" (Easton, et al., 2000, p. 707). By listening to the tapes more than once during this process, I became more familiar with the content giving me more opportunity to reflect on what the participants had said, how it was said, and what had not been said. This enabled me to make more effective choices of themes and sub-themes for further analysis of the data. The transcriptions, totalling in excess of 700 pages, were filed on the computer as well as bound into books according to the participant and the type of data gathering method, specifically student experiments, parent interviews, community interviews, and student focus group interviews. Having both hard and electronic copies of the transcripts, along with the electronic copies of the original videos and recordings of the interviews, allowed for quick, and easy access to the original interviews by the researcher and researcher's supervisors (Morse & Richards, 2002). The hard copies were stored in a locked cabinet in a locked office, and the electronic records were saved on a laptop requiring a password known only to the researcher.

3.4.3.5 Member checking

Due to the large number of interviews undertaken, and the difficulty as the researcher with the constraints of a full-time teaching principal position to conduct and transcribe these interviews within a short timeframe, it was not feasible to ask participants to review their own transcripts as a check to assess if their interview had been accurately recorded as a "recognizable reality" (Maykut & Morehouse, 1994, p.147). Instead, at the next interview I recounted the main ideas that had emerged to ascertain if they captured the essence of the meanings and views of the students. At the conclusion of the final interview, I summarized the main points raised and checked with the students to ensure they all were in agreement with my synopsis. This procedure worked well as the students were familiar with the process of a child summarizing the main points of literary texts read and then the group evaluating the accuracy of the interpretation and summary. For the adults, I used the technique of paraphrasing (for example, "Did you mean …") to ensure my subjectivity did not influence the data analysis.

3.4.4 Data analysis

The focus of this study was true to the philosophical intent in phenomenology, with the central research question focused on the meaning of the experience of a science intervention programme for the students in a very small rural primary school. By focusing on the meaning of the experience, the emphasis was on understanding rather than merely describing the experience. This influenced the type of data analysis undertaken in this research.

This study took the perspective that science learning is not only an individual but also a social activity (Gopnik, 2012; Jadrich & Bruxvoort, 2011). Therefore, student data was analysed from an individual and collective (social) level. Phenomenology focuses more on the individual's lived experience, whereas sociocultural discourse analysis recognizes classroom talk as a social mode of thinking (Tytler & Aranda, 2015). Discourse analysis was used to analyse the language within the group setting. Finally, *Tātaiako: Cultural*

Competencies for Teachers of Māori Learners (Ministry of Education, 2011) was used as a culturally responsive pedagogy framework to discuss the findings in relation to the students' rural culture.

3.4.4.1 Phenomenological analysis

Phenomenology is not about generalizing theories to other individuals or groups of individuals in the population. It is more concerned with the experience of a phenomenon – what the research participants experienced and how they experienced it as described in their own words. Hycner (1999) refrained from using the term data analysis for phenomenological inquiry claiming analysis suggests a "breaking into parts" with the possible detriment of viewing the totality of the whole phenomenon whereas explication implies an "investigation of the constituents of a phenomenon while keeping the context of the whole" (p. 161). While I acknowledge this as an integral part of phenomenological philosophy, I have continued to use the term data analysis in reference to the methods I used to interpret the data from phenomenological sources on the understanding that explication is implied in relation to phenomenological inquiry.

Phenomenological inquiry extracts significant statements about the phenomena, which are first clustered into meaning units, and then themes to create the development of what Moustakas (1994) defined as an essence statement about the phenomenon under investigation (Creswell, 2009; Hycner, 1999). In the present study, data from the focus group interviews, the science book covers and the students' reflective writing were read and reread in order to ensure familiarity and immersion into the participants' world. I then selected significant statements, sentences, or quotes that indicated how each student experienced school science, in particular the Chemistry Outreach programme. As researcher, I needed to consciously bracket my own preconceptions in order to prevent my subjectivity affecting the choice of statements. The attitude dimension was explored through the students' feelings about the Chemistry Outreach programme revealed in the interviews, book covers and reflective writing. Engagement with the Chemistry Outreach programme was explored through the students' reflections on the programme in their reflective writing and interviews. Long-term engagement was established through the students' responses to whether they would choose to be involved in secondary school science. The scientific skills dimension was examined through categorizing the skills students identified they were good according to procedural doing skills and procedural understandings (Feasey, 2012). The scientific language dimension focused on students' use of scientific language and the use of scientific discursive features.

After this horizonalization step (Moustakas, 1994), the significant statements were clustered into units of relevant meaning. The dominant meaning units were retained on the grounds of the number of times a meaning was stated, and by how many participants. These units of meaning were then examined within context to form clusters of meanings or themes. These themes were then summarized in an attempt to portray more of a holistic view of each student's lived experiences in relation to themselves and to others (Hycner, 1999). Once this process was completed for each student, I searched, "for the themes common to most or all of the interviews as well as the individual variations" (Hycner, 1999, p. 154). These variations revealed anomalies that offered an opportunity to add further depth to the understanding. Finally, I presented a summary of the themes within the research context (see Appendix F for an example of phenomenological analysis). A similar procedure was undertaken when extracting adults' perceptions of the community culture.

3.4.4.2 Discourse analysis

Discourse analysis focuses on language-in-use and ascribes to the belief that meaning is socially co-constructed through language. It involves the analysis of language within a social group setting, where "language both mediates and constructs our understanding of reality" (Starks & Trinidad, 2007, p. 1374). Classroom discourse is often analysed through the interrelationship between language and thought (Tytler & Aranda, 2015), where the internalization of knowledge is dependent on first, the sharing and refining of ideas at the social level before these concepts are understood by the individual (Vygotsky, 1981).

Discourse analysis can be perceived as an extension to phenomenology in that it moves the analysis focus from the individual to “the context of the culture as a whole” (Ashworth, 1997, p. 223). The analysis of data through discourse analysis entails the identification of “themes and roles as signified through language use” (Starks & Trinidad, 2007, p. 1376). In this study, discourse analysis was used as a way to reveal conscious and unconscious agendas, the establishment of social roles, and knowledge-creation by the participants within science group interactions. This enhanced the phenomenological approach, which revealed the science experience from the individual’s perspective. Discourse analysis was used to analyse the two videos of the group science activities with the focus on student-student/s discourse patterns and how they influenced the student learning within the group setting.

The engagement dimension was examined by focusing on the frequency of utterances, type of utterances such as procedural talk, observations, predictions, explanations and off-task talk, and the social interaction indicated through students’ discourse that could affect engagement (see 4.2.1.1). The scientific skills dimension focused on the discourse the students used which revealed the roles, such as task controller and task director, the students undertook within the group in relation to the procedural doing skills and procedural understandings (see 5.1.2.1). The scientific language dimension was explored by analyzing students’ discourses according to the interpretative role in language, (Sutton, 1998), that is, tentative speculations in meaning-making during the process of developing new understandings (see 5.2.2). Attempts at meaning-making involved discursive features such as repetitions, confirmations, elaborations, and revoicing of other group members’ ideas.

The analysis of student discourse within group settings acknowledges science as a social activity, and science classroom discourse as a social mode of thinking that attempts to make sense of the world (Mercer, 2008), Consequently, scientific knowledge is talked into being (Siry et al., 2012). By using phenomenology and discourse analysis insight is gained into the students’ lived experiences through their talk during science activities and about school science. As a result, their reality was established through the uncovering of the meaning of their experiences during individual and social interactions.

3.4.5 Ethical considerations

The central goal of this phenomenological research is to develop a deep understanding of the lived experiences of a phenomenon, namely the Chemistry Outreach programme, as described by the participants. Young children aged from eight to eleven were included in this phenomenological study as research participants. I come from the perspective that the children involved in this research are regarded as competent social actors willing to participate in the study. As a researcher, I took a reflexive position throughout the whole research process, questioning my values and actions, as this viewpoint does not necessarily mean the research should always be undertaken in the same way as with adults (Goodenough et al., 2003; Punch, 2002b). It is from this standpoint in research with children that I will elaborate on the approaches I took regarding issues of informed consent, power relations, and confidentiality with research involving children. My primary concern throughout the whole research process was the welfare, the safety, and the protection of these children as research participants, therefore I endeavoured at all times to proceed in a sensitive way to "enable children to be heard without exploiting them, protect children without silencing and excluding them, and pursue rigorous inquiry without distressing them" (Alderson & Morrow, 2004, p. 12). I also explain the process taken with the adult participants.

3.4.5.1 Informed consent

Informed consent involves the expectation that before participants decide to give their consent they have been fully informed about the research project (Lindsay, 2000). It is premised on respect for the individual's freedom to choose to participate if it is deemed they have the necessary cognitive competence to make the decision. This decision is voluntary, not influenced by "physical or psychological coercion" and is "based on full and open information" (Christians, 2011, p. 65) about the nature and purpose of the research including any possible emotional or physical harm**.** Ethics approval for this research study was granted by the University of Otago Human Ethics Committee, and the conditions have been adhered to throughout the research process. As ethical issues have the potential to arise at any time (Kvale, 1996), every attempt was made to respect the rights and the privacy of the all the participants throughout the research process.

3.4.5.1.1 Informed consent with children

Considerations of cognitive competency, age appropriate information, and voluntary consent are particularly relevant to research with children (Kirk, 2007). A significant issue that arises with research with children is "the question of who is to be informed and who is to give consent" (Powell & Smith, 2009, p. 135). Before commencing this research with children, it was necessary to obtain consent from a succession of adult gatekeepers. Initially, ethical approval was required through the University of Otago, as it was through this institution that the research was undertaken as the requirements for a Doctor of Philosophy. Ethical approval involved outlining a detailed account of the process for gaining informed consent via adult gatekeepers to include children as research participants. This entailed approaching the research school's Board of Trustees to approve this research access. As I was the school principal, it was not deemed necessary to officially seek my approval. However, undertaking research in the school where I was principal could have implied ethical and/or power relationship issues. Therefore, to ensure the Board was fully informed, it was necessary for me to explain the potential benefits for the children, parents and community of participating in this study, and to leave the decision for participation up to the Board of Trustees. Once the Board of Trustees approval was gained, I contacted the parents and children.

Although parental consent was required on behalf of every child (Appendix G1), it was also part of the ethics requirements to ask the children for their agreement**.** I explained to the children as a group what the research was about (the Outreach Science programme at their school) and that by talking and doing science activities they would be helping me find out what they think about science. I explained that this would be written into a report but their names and the school's name would not be mentioned. I also explained what confidentiality meant and that I would ensure their privacy by keeping private anything they said to me. In an attempt to ensure informed consent for these children, age appropriate written information about the purpose and nature of the research process, including what participation would require, was given to each child to take home to discuss with their parents (see Appendix G2). Each child was asked to sign a consent form, which also informed them they could withdraw from the study at any stage without any consequences (see Appendix G3). Only two children from the same family chose not to take up this option, even though they were willing to participate in the research. This was possibly due to their parents not seeing the relevance of their children signing the consent form when they had already done so as adults for their children, and therefore influenced the decision on behalf of their children. However, most other parents commented on how their children felt very important and grown up when signing their own consent form.

Although I recognised the competency of children as informed participants, I concede that by having to work within institutional constraints imposed on the research process, access to the children was largely through those who had power over them. This begs the question as to whether consent was actually given, or was it more a case of assent (Morgan, Gibbs, Maxwell & Britten, 2002), or compliance from the children's perspective (Pole, Mizen & Bolton, 1999). With regards to whether the consent was informed, children's age, general cognitive ability, emotional status and knowledge can affect their understanding of the information presented regarding the research process (Lindsay, 2000). From my adult perspective the research was of a non-intrusive nature with the interviews very similar to discussions the children are familiar with in the classroom context. However from the child perspective, because they had never been in a situation of being interviewed before, the whole process of gaining informed consent may possibly have created stress and anxiety that wasn't intended as highlighted by a child saying after signing the consent form, "Well, that wasn't so bad after all."

I acknowledge that the issues regarding informed consent for children can be complex and at times controversial. Throughout this research process I have endeavoured to the best of my ability to ensure the children felt that they were consenting in an informed way to their ongoing participation in this study. This is further elaborated in the power relations section.

3.4.5.1.2 Informed consent for adults

All aspects of the research, including the nature and purpose were explained to each adult before the written consent form to participate in this research study were signed. Participation was entirely voluntary, therefore the participants were under no obligation to take part in the study. Furthermore, they had the option to withdraw at any stage should they wish thereby "counteracting any potential undue influence or coercion" (Kvale, 1996, p.112). This meant that even if an adult participant decided to discontinue, the Chemistry Outreach programme would still continue in the classroom for the children. No adult participants withdrew from the study, but had this occurred, all their audiotapes and transcripts would have been destroyed.

3.4.5.2 Power relations

It is essential to reduce any researcher/participant power inequalities to ensure participants consider researchers have "a feeling of empathy" towards them so they "open up about their feelings" (Taylor & Bogdan, 1998, p. 48). This can involve ethical and methodological considerations (Karnieli-Miller, Strier & Pessach, 2007).

3.4.5.2.1 Power relations with children

I had already built a relationship with these children, and their parents, through my role as both principal and teacher. However, I was aware that ethical issues might arise at any stage during the research process due to the power differential between the children and me, as an adult, in the dual role as researcher and their school principal/teacher. Having acknowledged a possible power advantage over the student participants, it is important to document the seven strategies used in an attempt to minimize this power imbalance. These strategies included using focus group interviews, rehearsal techniques, the use of an advocate for the children, natural settings, observations, care and compassion, and the analysis and presentation of children's data.

First, focus groups were used for the children's interviews**.** The children were interviewed in small focus groups of five to six children of similar age. Focus groups can be a children friendly research method (Morgan & Krueger, 1993), as the power and the authority of the researcher is replaced by a facilitatory role within a respectful and non-condesending atmosphere (Kamberelis & Dimitriadis, 2011; Morgan & Krueger, 1993). It could be argued that the use of focus groups does not fit in with the philosophy of phenomenologigal research which explores individual's experiences. However, the positive influence of group dynamics can help participants develop their thinking further thus making focus group interviews, "especially useful for investigating what people think and for uncovering why people think as they do" (Mayhut & Morehouse, 1994, p. 105).

Second, rehearsal techniques were used to give the students confidence in not answering interview questions should the occasion arise. Prior to the commencement of the interviews, I practised with the children different ways of indicating that they did not either want to answer a particular question, or did not know the answer to a question (Kirk, 2007). This made it easier for them to articulate their refusal or lack of knowledge in a non-threatening way that would hopefully not harm their self-esteem and self-confidence.

Third, a children's advocate was used during the interviews**.** Although parents were invited to be present at these interviews if they so wished, none of the parents accepted the invitation. After viewing the interview schedule (see Appendix C), several parents commented that the interview situation would be very similar to group discussions teachers would hold in the classroom. Despite this assurance, I still took the added step of employing a person from the school whom all the children knew to act as their advocate. The advocate's role was to provide support and assistance by being available to withdraw any children who felt threatened, uncomfortable, or distressed during the interview. This was explained clearly to the children at the outset of the interview and during the interview so they were aware that if they were unhappy with the interview situation for any reason, they could leave with the advocate without having to justify their reasons. No child used this opportunity to withdraw at any stage during the research process. In fact, several children voiced their disappointment when the interview session finished, as they stated they had enjoyed the process. They attributed the interview as being similar to class discussions, but more important as they were being recorded.

Fourth, the interviews were conducted within a familiar natural setting. As qualitative research is generally conducted at the site where the participants experience the phenomena under study (Creswell, 2009), it is natural to expect this research to take place at school where the children participated in the science programme. However, the school setting with its hegemonic power and authority structures mirrors the adult-child imbalance of society (Pole et al., 1999; Sligo, 2001). Children are aware of the authoritarian role principal and teachers have within the school. Furthermore, children are aware of the expectations of appropriate behaviour within this social context (Sligo, 2001). These adult-child power dynamics are acknowledged and to help minimize possible power differentials in this study, children were interviewed in a familiar setting within the school grounds such as the classroom and the library. It was also explained to the children that there were no right or wrong answers, as I was interested in their personal feelings about science.

Fifth, observations were undertaken in a way that was as natural as possible for the children**.** Observations took place within the classroom setting, during normal classroom sessions. Although the children were aware that they were being recorded during their involvement in science experiments, the micro-cassette recorders were discretely located some distance from where they were working. After setting the task with the children, I involved myself with other students in the room, as in usual classroom teaching practice, so the children did not feel my omnipresence as the teacher and were able to concentrate on the task at hand. However, I was able still able to observe and take occasional field notes about actions, such as who was doing the measuring of the liquids, that would compliment the recordings.

Sixth, efforts were made to ensure children were treated with care and compassion. Prosser (2011) recommends any “ethical decisions are made on the basis of care, compassion, and a desire to act in ways that benefit the individual or group that is the focus of the research (p. 494).” Throughout the duration of the interview session, I monitored the ongoing consent of the participants (Kirk, 2007; Munford & Sanders, 2004), checking the children’s willingness to continue participation by noting any non-verbal cues that could arise such as yawning, fidgeting, or appearing distracted, and by regular verbal prompts such as “Are you happy to keep going?” before continuing. There were no occasions where the children displayed any non-verbal cues, but I still used verbal prompts to give them the opportunity to stop the interview should they wish. No child indicated that they wished to discontinue with the interview.

Seventh, care was taken with the analysis and presentation of the children’s data. Data gathering methods with children represent particular behaviours bound within a specific social context and therefore “all data needs to be fully contextualized” Connolly, 2008, p. 184). The writings of some feminists argue that despite attempts researchers make to reduce the power differential between participants and researchers, the researchers hold the ultimate power, having control over the data analysis and presentation (Cotterill, 1992). Nevertheless, I consider it a moral and ethical obligation to make an effort to fairly represent the children’s experiences in their terms. Using children’s own language by incorporating quotes from the interviews and observations can help to minimise what Hendrick (2008) calls “adultist bias” (p. 46).

The aforementioned strategies involving focus group interviews, rehearsal techniques, children’s advocate, natural settings, ethics of care, data analysis and presentation were employed throughout the research process. The strategies helped me to minimize, but not necessarily completely eliminate, possible power imbalances between me, as an adult teacher and a researcher, and the children, as student research participants.

3.4.5.2.2 Power relations with adults

Interviewing can be compared to a relationship within a certain social context (Seidman, 2006). The social context for this study was the school environment where I had a multiplicity of roles as principal, classroom teacher, and researcher. The adult participants being interviewed were either parents of the children I taught, or belonged to the community where I was the new principal of the local school. As a result, there were inherent power relations ranging from parents wanting to be seen to be on the 'right' side of the principal of the school their child attended, to community members, who were very proud of their community, and were endeavouring to give the right impression to a newcomer who as principal of the only school in the community had inherited a respected standing in the community.

I made a concerted effort to develop a rapport with the adults. For instance, I shared my impressions of the rural community that I live in, before asking them to reflect on their community. I was aware that doing so may influence their responses, so if I found that they seemed to reiterate points I had made, I asked them to give examples or elaborate to confirm in my mind whether or not their responses had been affected by my disclosures. However, I had to be careful not to be too friendly, as I did not want to be involved in personal opinions about other community members and their actions.

3.4.5.3 Confidentiality

Confidentiality involves removing any information that could lead to the identification of any of the participants in a research project to avoid any embarrassment or harm (Berg, 2001; Bogdan & Biklin, 1998). Researchers need to be transparent in the steps they took to ensure the confidentiality of their research participants.

3.4.5.3.1 Student confidentiality

Initially, I was intending for the children to select their own pseudonyms. However, I was well aware that the novelty of having a 'research identity' could tempt the children to share their pseudonyms with each other. Therefore, using researcher generated generic gender identifier names and class level, for example 'John, male Year 4 student' or 'Lisa, female Year 6 student', ensured the protection of the children's identities. Any identifying contextual details were sufficiently disguised within the text to avoid identification by the reader. Furthermore, no information elicited during the data gathering process was disclosed to any person connected with the child, including parents and teachers (Masson, 2002). I stressed at the beginning of each interview that the focus was on their experiences of science and encouraged them to keep to the topic. I was aware that although the information they were giving me was not necessarily of a sensitive nature, it was a public account of a personal view. Essentially, they "are not privatized experiences; they are public understandings given voice through these individuals" (Hardin, 2003, p. 538), and needed to be respected as such. I sought to maintain a climate of trust and mutual respect, encouraging children to respect others' contributions, to keep what was said in the interview within the interview room, and to realize that I, as researcher, was upholding the same values.

3.4.5.3.2 Adult confidentiality

This research was located within a small, close-knit rural community, so there was always the possibility that an adult participant could be recognized in a personal or professional capacity. Few participants would be open and honest with their innermost thoughts if they knew there was a possibility of being identified in the published report (Patton, 2002). As with the children, I took all possible steps to ensure complete confidentiality of all the adult participants by using pseudonyms for them, the people they referred to, the school, place names, and any other identifying information. I encouraged the participants not to discuss details from the interviews with anyone but myself, as researcher. In return, I assured the participants that no information obtained during the course of this research would be discussed with anyone, except my supervisor, without the written permission of the participants.

As a teacher and researcher I was also aware of the difficulty in such a situation of maintaining critical detachment, or of being objectively subjective. Therefore in the interests of confidentiality, I limited discussion of topics arising from interviews to the times when data collection was formally scheduled. Several occasions arose when participants, in particular parents, wanted to continue discussing a topic arising from the interviews. In those cases we either moved to a private area or ensured no one else could hear our conversation to ensure confidentiality.

3.5 Summary

This chapter has outlined the theoretical framework of this research and detailed the different stages of the research process, culminating in an explanation of the ethical considerations undertaken in order to ensure the welfare of all participants involved in this study. In the following three chapters, the visual and spoken texts are described and interpreted according to the theoretical and methodological positions framing this research as outlined in this chapter. The next chapter looks at the themes of attitudes towards school science and engagement with school science.

CHAPTER FOUR
ATTITUDE AND ENGAGEMENT

4.0 Introduction

The focus of this study is rural primary school science in response to the lack of longitudinal research undertaken in this area of science education prior to Year 8. Specifically, it investigates the influence of a year-long science initiative programme on Year 4-6 rural primary school students' attitudes towards and engagement with school science, along with the use of science skills and scientific language. There is a need for this research as evidence indicates a declining interest shown by New Zealand students in science education in the later years of primary schooling (Bolstad & Hipkins, 2008; Bull et al., 2010; Gluckman, 2011; Hipkins et al., 2006).

This chapter and the following chapter present the students' lived experiences of a science programme involving the school and the University of Otago Chemistry Outreach team. Phenomenology views pedagogy as involving the heart (feelings), the hand (actions), and the head (thinking) (Henriksson & Friesen, 2012). In this study, examination of the affective domain (feelings) will reveal the students' attitudes towards science, the behavioural aspect (actions) will indicate their engagement with science, and the cognitive perspective (thinking) will reveal the students' use of scientific skills and language. Each concept, namely attitude, engagement, scientific skills, and scientific language will be examined separately and in-depth. Although these concepts and the resulting sub-themes are categorised as four separate entities, in reality, the parameters between them may overlap.

There will be an indication at the beginning of each section as to the definition and the specific data sources used to explore the identified concept. Results were recorded individually for each child over the duration of the year-long programme and these will be examined to establish any changes over time. Next, further aspects relating to the concepts which were spoken at length, or discussed by several students will be examined.

Engagement, scientific skills and scientific language are also examined from the collective perspective in order to establish social influences on these concepts. The final part of each section will discuss the results including how they support, extend or refute the existing research literature.

The interpreted findings reported in this and the following chapters relate specifically to the following main research question (see 1.3): What are rural primary school students' experiences of a Chemistry Outreach programme? and the subquestions: How does the student's experiences with a Chemistry Outreach programme change their attitudes towards school science? How does the student's experiences with a Chemistry Outreach programme change their engagement with science and their intention to continue with school science? How does the student's experiences with a Chemistry Outreach programme change their use of scientific skills and language? How does the Chemistry Outreach programme respond to the students' rural context and upbringing?

4.1 Attitude

The definition of attitude towards school science used within the context of this present study is confined as far as possible to the affective aspect (Ajzen, 2001; Crano & Prislin, 2006: Petty, 2012). The focus is on the affective responses, or the feelings, students have towards the Chemistry Outreach programme, albeit favourable or unfavourable, positive or negative, and any feelings in between.

The data were generated through focus groups interviews, students' reflective writing at the end of the programme, and any comments they made on the designs they created for the covers of their science books. References will be made to the phase of the programme when the quote occurred. Phase one, which was an introductory cycle designed to put the 'wow' into science, included demonstrations by the scientists[6] and some student hands-on science activities related to the different states of matter. The second phase involved the students in the preparation, planning, and doing of activities related to pH. The third

---

[6]To avoid confusions between students from the school and the university, the Chemistry Outreach Team University staff and students will collectively be referred to as scientists.

phase was when the students planned, designed, conducted and evaluated their own scientific investigations involving pH in their community.

In order to track any changes in students' feelings over time there will be an indication as to when the quote was said or written. FG1 relates to the first focus group interview which occurred before the scientists had visited. FG2, the second focus group interview, took place mid-way through the programme, in other words, during phase 2. The third focus group interview, FG3, occured at the completion of the programme, at the end of phase 3. The text will indicate which phase the focus group comments referred.

The children participated in the reflective writing at the end of the programme, but the coding indicates the phase of the programme they are writing about. For example, if they wrote about their feelings during phase one of the programme, this will be coded as WR1 even though it was recorded at the end of phase 3. The science book covers were designed during phase 2 and therefore are all coded BC2.

Through the analysis of the data, two predominate themes emerged. The first theme related to the emotional connectedness with the subject matter, that is, the science programme. The second theme was concerned with the relational connectedness with the people, that is, the Chemistry Outreach scientists. As outlined in the Methodology Chapter, the purpose is not to make value judgements about either the students or the people with whom they interact, but to examine from a phenomenological stance how the students experienced this programme, as described in their own words.

4.1.1 Emotional Connectedness

Students' attitudes towards the Chemistry Outreach programme are the result of their evaluative judgement according to emotional aspects such as favourable or unfavourable; enjoyable or not enjoyable (Ajzen, 2001; Crano & Prislin, 2006; Petty, 2012). Attitude is not a static, fixed concept and therefore can be predisposed to change (Ajzen, 2001; Wilson, Lindset & Schooler, 2000). The present study wanted to investigate if and/or how students' attitudes change over time towards the Chemistry Outreach programme. During this time of attitudinal change it is possible for the student to hold two somewhat contradictory or diverse attitudes towards the programme, as the new attitude dominates the student's thinking but may not completely suppress the original attitude. This can lead to ambivalent feelings until resolved in favour of either the original attitude or the new attitude.

The students voiced a range of emotions when describing how they felt about the science programme. For some students, their initial feelings were consolidated over the duration of the programme, whilst for other students their reponses changed as the programme progressed. These are described below under the sub-themes of locking in already existing positive attitudes: positivity tinged with reservations**;** and journeying towards positivity.

4.1.1.1 Locking in already positive attitudes

For Shane, Kelly and Ken, the science programme locked in their already existing positive attitude towards science. They were all very positive in their attitude towards science prior to the commencement of the programme. Shane loved science, describing science as "fun, awesome" and was feeling "excited" about the programme (WR1). Kelly could hardly contain her amazement and excitement about the programme, "When the scientists came to school I couldn't believe my eyes - real scientists at school!" (WR1). Ken was similarly excited about the prospect of the Chemistry Outreach programme becoming part of the classroom science programme, declaring, "Science - it's cool" (WR1). They all saw the programme as an opportunity to extend their natural curiosity about the world they live in and the way it works, "Being a science student is really fun because science is about the world" (Shane, WR1). This positiveness continued throughout the duration of the programme with Ken acknowledging, "Science is awesome" (BC2), and both Kelly and Shane stating that they "love science" (Kelly, BC2; Shane BC2). This was reinforced in phase 3 with Shane re-emphasising he found science "fun" and "awesome" (WR3), whilst both Kelly and Ken thought science was "really cool" (FG3).

4.1.1.2 Positivity tinged with reservations

Although Peter, Maree and Lisa initially felt very favourable towards the science programme, these responses fluctuated as they all went through a stage whereby their emerging self doubts negatively influenced their reactions before they finally returned to their original positive attitudes. These responses are now explored further.

Peter's initial emotions towards the science programme were positive, **"**When I started science I was excited to know how it works" (WR1). But, by phase 2 this excitement was tinged with an element of unease and anxiousness, particularly in relation to working in the unfamiliar context of hands-on science experiments, "When I had a go at my first experiment I had a tingly, great, wonderful, happy, excited, pleased, good, speechless, interested, enjoyable, concerned feeling inside me." (WR2). It was interesting to note after a list of ten positive responses, Peter included a "concerned feeling" indicating some self-doubt. He may have been influenced by the fact that he was wearing safety glasses and using scientific equipment similar to practising scientists and had imposed expectations on himself of 'getting it right' and 'knowing what to do'. By the end of phase 2, these reservations had waned and he stated, "I love science. Science is awesome" (BC2). These positive feelings were consolidated in phase 3, with Peter regarding science as enjoyable and beneficial as, "not only you're finding out different stuff, but it is fun to do cause you learn different stuff" (FG3).

Maree also experienced a range of emotions towards science throughout the programme. Her initial reaction before the beginning of the Chemistry Outreach programme was that of excitement combined with apprehension of the unknown, "nervous…heart pumping … waiting to see what the scientists would do on first time - didn't know what to expect" (WR1). However, the anxiety to please the adults coloured her reactions during the initial stages of phase 1, as evidenced in her comment about an activity that took place during the third visit by the scientists:

> I didn't know if I was doing it right. I started and I wasn't meant to. I didn't know what to do and I said do it again in the 20 / 20 test and I wasn't meant to and I felt silly because I knew after a while it was a dumb answer (WR1).

The scientist's response to Maree in this scenario was supportive and encouraging, assuring her that her answer was a possible solution to the question he had asked. Despite this reassurance, it was the beginning of the phase 2 after the scientists' sixth visit, before this insecurity and anxiousness had diminished when she commented, "Science, it's fun" (BC2). By the end of phase 3, she was feeling "excited" about science as it was "fun" and she had "good memories" of the science programme (WR3).

Lisa's initial response to science was very favourable, "Yay, time to learn about science." (WR1). But while watching one of the initial sessions she was overcome by a lack of confidence and this self-doubt resulted in her sitting back and watching rather than participating in the experiment:

> I love doing science but I felt terrified because of the fire exploding. I watch a few people do it then I thought I just can't do it. My hand might get burnt. I ask if I have to do it. Yah! I don't have to. I sit down happily and all my friends do it (WR1).

From the security of knowing that she would not be forced to participate in the fire experiment, Lisa was able to observe her peers in action prompting her to comment, "I was amazed how easy it looks" (WR1). The confidence and enjoyment displayed by her peers helped to reassure Lisa and encourage her to participate in the hands on experiments in phase 2. By the end of phase 2 she declared, "I love science. I love, love science!" (BC2), and in phase 3 she emphasized that science was "fun" (FG3).

4.1.1.3 Journeying to positivity.

Three students, Tom, Jerry and John, were not favourably disposed towards science and consequently were not looking forward to the science programme starting at the school. By the second visit in phase 1, two of these students had changed their minds with the third student reevaluating his judgement by the beginning of phase 2.

Tom's impressions about science being boring, not very interesting and hard to understand were reinforced by the first Chemistry Outreach visit, "Before they came I thought science would be boring. I was not interested in science. When they arrived I did not get a thing they said." (WR1). However by the second visit during phase 1 of the programme his attitude towards science was changing:

> Next week we had this science day. That got me interested in science watching them putting fire on their hands. Then we had to do it. I felt like I was going to no longer have a hand! But the fire was sitting on my hand. I did not feel a thing. That's my favourite thing to do (WR1).

By phase 2, he was adamant that, "Science is the best thing that happened to me" (BC 2), and confirmed in phase 3 that science was, "fun" (WR3).

Jerry had similar reservations about science, viewing science as somewhat academic and dull, "I thought that science wasn't fun. I thought it was pretty serious" (WR 1). However, the second visit by the Chemistry Outreach team during phase 1 initiated a change in his attitude as he became aware of the possibility that science could be fun and interesting, "I realized it was a fun day because the scientists were trying to make us interested in science" (WR1). By phase 2 he declared, "I love science. Science rocks!" (BC 2), and in phase 3 he was adamant that science was "extremely cool" (WR3).

John viewed science as, "really boring" and he was concerned, like Tom, that he would have difficulty understanding the scientists, "because they probably only talk about science all the time … They'd be smart, and there would be too much smart stuff that you won't even understand their words" (FG1). However, he found his initial preconceptions of the programme were not realised and by the beginning of phase 2 he was hooked into science, "I love science" (BC2). At the end of phase 3 he summarized his feelings towards the programme by stating, "science is fun" (FG3).

At the end of the programme, each student spoke of a positive emotional connection with the science programme. There were differing paths taken by the students, but all the participating students reported positive feelings by the end of phase 2 and these feelings continued for the rest of the programme. For the first group, Shane, Kelly and Ken, the programme locked in their already positive attitudes towards the science programme. They took great pleasure in the entire science experience, could see the relevance of the learning, and reported that their enthusiasm and enjoyment remained high throughout the programme.

The second group, Lisa, Peter and Maree, experienced positivity tinged with reservations whereby they were initially positive but they all experienced a period of self-doubt before returning to a positive attitude. Lisa's positivity was replaced by a lack of confidence and self-doubt as she questioned her ability to take part in the fire experiment early in phase 1, even though it looked exciting. Although she decided not to participate in the experiment, she enjoyed watching her friends participate. As a result of her peers' example, her ambivalent feelings receded and she approached the rest of the programme, including the hands on activities, with self-confidence.

Peter's feelings of anxiousness started to develop in phase 2 as a result of working in an unfamiliar context of hands on science activities and self-imposed expectations of getting it right. This unease waned as the programme progressed because he was enjoying the activities and was starting to develop an appreciation of the knowledge he was gaining. Similarly, Maree also expressed apprehension during the hands on activities in phase 2. Like Peter, she was focused on doing it right and felt inadequate when she considered she was not meeting the required standard. As the programme continued, her insecurities subsided and she became more positive about the programme.

The third group, Tom, Jerry and John, experienced a journey that went from negativity to positivity. The first visit by the scientists confirmed Tom's initial impressions of science being a boring, difficult subject. The second visit in phase 1 ignited his passion for science and from then on he was enthusiastic about science. Likewise, Jerry had preconceived ideas of science as a dull, uninspiring subject. Similar to Tom, Jerry's attitude changed during the second visit of phase 1 when he realized that the scientists wanted to share their passion for science with him. As a result, he found that science could be fun and interesting. John's initial preconceived ideas of science as being boring, and scientists as difficult to understand dissipated as the programme progressed and by phase 2 he was enjoying science.

4.1.1.4 Underlying Influences

Although the students were asked to describe how they felt about the science programme, they were not specifically asked why they had the particular attitude they did towards science, or why they thought their attitudes towards the school science programme had changed or stayed the same. It was through the students talking about their experiences that the underlying influences were revealed that could attribute to these shifts in attitude. These influences, which include the scientists' passion for science, the acceptance of errors, and the power of peers, are now explored further.

Passion for a curriculum subject, "requires a love of the content, an ethical, caring stance deriving from the desire to instill in others a liking, or even love, of the discipline taught" (Hattie, 2012, pp. 16-17). For instance, Jerry's attitude changed when he realized the scientists were passionate about science and wanted to share that passion with him. He appreciated that the scientists were committed and enthusiastic enough to interest him in their passion for science, and wanted him to succeed in this area. Through their actions, the scientists were examples for the students of living science, being science and embodying science.

Errors are “the difference between what we know and can do, and what we aim to know and do” (Hattie, 2012, p.115). They represent mistakes or misconceptions resulting from incomplete knowledge or understanding. For this reason, they present a valuable insight into what the students have achieved and where they need to go next in the learning process. To illustrate, Maree initially felt very vulnerable, admitting to making mistakes, “I started and I wasn’t meant to,” lacking in procedural knowledge, “didn’t know what to do,” and feeling inadequate when it come to content knowledge, “felt silly because I knew after a while it was a dumb answer” (FG3). This tension between what she knows and what she could know does not dissipate immediately but over time, so that by the end of phase 2 she was more secure and relaxed enough to accept errors as part of her learning process. A classroom climate that welcomes errors as part of the learning process develops from trustful relationships between students and teachers. Trust reduces uncertainty and anxiety, so students can focus on learning (Tschannen-Moran & Hoy, 2000). This trust aspect is explored further in the following relational connectedness section.

The power of peers in the learning environment can be very persuasive and positive given the right supportive climate (Hattie 2012; Nuthall, 2007). An individual’s attitude toward science can be influenced by the attitude of his or her peers (Osborne et al., 2003; Taconis & Kessels, 2009). To illustrate, Lisa acknowledged her friends’ attitudes helped her overcome her reticence to participate in one of the early science activities. By seeing the way her peers interacted with the learning, Lisa was able to work through the challenge that the activity presented her. Peers can influence learning through a variety of ways including emotional support and friendship (Anderman & Anderman, 1999; Wilkinson, Parr, Fung, Hattie, & Townsend, 2002).

The findings in relation to the students’ emotional connectedness with the science programme highlighted three important considerations: first, the importance of understanding the nature of the attitudinal concept; second, the awareness of underlying factors that may influence students' attititudes, and third, the implications for the learning situation. These are explored further.

Attitude is a highly personal response to a learning situation, unique to each specific student. This means that students can perceive the same learning environment in different ways. These affective outcomes are special to each individual as, "no two children are alike or experience a situation in exactly the same manner" (van Manen, 1986, p. 12). Therefore, although teaching and learning takes place within a social context, the affective response to, "learning is always an individual affair" (van Manen, 1991b, p. 155). The variability of individual attitudinal responses towards the science programme and also the changes of attitude over time indicating the non-static nature of the attitudinal concept reinforces the need to be simultaneously aware of, "the students individually and as a group" (van Manen, 1991a, p. 517).

Underlying influences on students' attitudes towards science arise from the students' innermost thoughts, what Nuthall (2007) refers to as the private world of the students' own mind. Therefore, it is not the way that adults perceive the learning environment, but "ultimately more important is how the students *experience* them (van Manen, 1999, p. 21, original italics).

In learning situations, students' attitudes may differ from their classmates, may fluctuate over the duration of the lesson or programme, and may be affected by different influences. This personalised response to learning highlights the fact that effective teaching and learning is more than content knowledge and pedagogical techniques but is about people, the students and the teachers, and how they relate to each other. This is explored in the next section as relational connectedness.

4.1.2 Relational Connectedness

In this study, relational connectedness refers to the relationships with and among participants in a social group, specifically the students and the scientists. Relationships are an essential part of the educational experience (Gibbs, 2006; Giles, Smythe & Spence, 2012) and research has shown that positive student-teacher[7] relationships are powerful influences on student learning (Cornelius-White, 2007; Frymier & Houser, 2000; Hattie, 2012). Palmer (1998) in his seminal book *The Courage to Teach* placed more importance on relational connectedness than pedagogical techniques and subject content in the learning process. In this present study, the scientists' role was comparable to that of a teacher, consequently the relationship between the students and the scientists can be likened to a student-teacher relationship.

The students spoke and wrote at length about how they viewed their personal relationships with the scientists. These relationships were very important to them as, "students tend to experience instructional relations as personal relations. It matters to them how they matter to their teachers" (van Manen,1999, p.23). This student-teacher relationship is revealed through three sub-themes of interpersonal connectedness, reciprocal trust, and humour.

4.1.2.1 Interpersonal Connectedness

Interpersonal connectedness refers to the strong personal connections formed between the student and the teacher (Hattie, 2012). It occurs when students and teachers transcend the more traditional formal relationships, where the teacher is deemed to possess the majority of the knowledge and the power, and start to relate to each other as unique individuals (Frymier & Houser, 2000). In this study, the students revealed that the scientists meant more to them than science experts.

---

[7] Research literature often refers to the relationship between the student and teacher as the teacher-student relationship. I have purposefully used the term student-teacher relationship to emphasise the primacy of the student experience in keeping with the phenomenological perspective in this study.

The students' preconceived expectations of what the scientists would be like were not matched in reality. Lisa expected them to be self-absorbed in science and not really interested in the school children. She imagined the Chemistry Outreach visits would involve the scientists, "sort of like in the staff room eating and talking about their science all day" (Lisa, FG3). Kelly commented, "they weren't like we thought they were. They weren't like nerdy and they weren't always talking about smart things" (FG 3). Consequently, the students enjoyed the scientists coming to the school as they were, "really nice people" (Maree, WR2) and, "they're actually interesting' (Kelly, FG3). Furthermore, the students didn't expect the scientists to be so young "about in their teens" (Peter, FG3) and appreciated the fact that the students were closer in age than their teachers, "they are younger than some of the teachers, and they understand what we mean" (Maree, FG3). From the students' viewpoint, this insignificant age differential between the students and the scientists gave them more of a generational closeness and understanding.

Several students commented on the fun aspect they experienced with the scientists not only when playing cricket but also during lessons, "they're really fun to play with" (Shane, FG3); "fun to be with" (John, FG3); "fun having them around us … you have a really good time with them" (Maree, FG3); "they're fun" (Lisa, FG3). This fun relationship with the scientists was very important to the students as they believed the scientists were genuinely interested in them as people, "they enjoy, enjoy us kids" (Shane, FG3).

In return, the students appreciated the opportunity to get to know the scientists as people. At the end of the year, the scientists came early to join in a lunchtime cricket match with the students. This made a great impression on the students who were passionate, competitive sportspeople, and were all involved in out of school sports competitions. Kelly revealed that she, "never thought that scientists would play games with us. I just thought that they would do some work with us, just talk about different types of chemicals and…then they would just pack up and leave" (FG3). Even though the scientists did not win the match, the students admired their fortitude in persisting in the game, “these scientists were really sporty” (Shane, FG3).

The cricket match proved to be one of the triggers that helped to consolidate Jerry’s evolving positive feelings towards science. Cricket was a context in which he did not feel the inbalance of power often experienced between teachers and students, or adults and children. He was a capable cricket player and soon realised that he was on an equal standing with the scientists when it came to cricketing skills. The shared experience of the cricket match helped to redefine his relationship with the scientists, making him feel more connected and relaxed with them. This in turn made him more receptive to making positive connections to the subject matter the scientists were teaching. “I think the scientists from [Chemistry] Outreach are really helpful and playful. They have never made me feel left out like when Gary[8] was playing cricket [with us]. Then I realized this [Chemistry] Outreach is better at science” (Jerry, FG3).

Interestingly, Jerry was the only student who took the expectations of this relationship further, associating the combination of science teaching and the cricket session as a basis for forming a friendship, “I have been feeling good because I am making a really nice friend like Gary. He is friendly because he lets us do new [science] stuff and play with him” (Jerry, WR3). Jerry’s expectation of a friend relationship between student and teacher is contrary to the findings by Henriksson (2008) where students preferred teachers to be friendly with them but not to become their friends.

The students perceived they had formed strong interpersonal connections with the scientists and they believed this to be a reciprocal relationship that flowed from student to scientist and scientist to student. Consequently the students felt more connection with the subject matter the scientists presented. This strong interpersonal connection was further enhanced by a climate of trust which is discussed further in the next section.

[8] Gary is a pseudonym for one of the scientists.

4.1.2.1.1 Trust

Trust is essential for all healthy human development (Garbarino, 2010). A young child initially experiences trust within the home environment through the closeness of the parent-child relationship. In this atmosphere of trust the young child feels cared for, protected, and secure. This encourages and supports the child's trust in themselves and others as they begin to explore the world around them, interact socially with the people they meet, challenge themselves both physically and mentally, and strive to become more independent. Hence, trust can positively influence the social, emotional, and overall personal growth of the child.

In three decades of teaching experience, I have found a trustful relationship between student and teacher is conducive to a caring and supportive environment for the academic, social, and emotional growth of the student. From the perspective of the student, trust is the most favourable aspect of the learning environment (Bollnow, 1989). A trustful student-teacher relationship is paramount to ensuring effective teaching and learning occurs in the classroom (Hattie, 2012; Nuthall, 2007; van Manen, 1991b). Therefore, building a trustful relationship between student and teacher is positively associated with improved student capacity to develop positive attitudes towards subject matter and consequently to learn (Bryk & Schneider, 2002; Hattie, 2012; Nuthall, 2007; Lilja, 2013). Several students acknowledged a relationship of trust with the scientists by the second phase of the programme. Key elements of the student-teacher trust relationship highlighted by the students included: authenticity; time; security; reciprocity; self-belief; and the acceptance of not knowing .

The students acknowledged the scientists as being real or authentic, "I trust them more [than teachers] because they've had the practice before they come here and do it" (Tom FG2). Their scientific expertise, their knowledge and experience are valued and consequently some students perceived the scientists to be more credible as science experts than the generalist classroom teacher (Forbes, 2014).

The students appreciated the time the scientists spent with them, “They do so much stuff with us and we’ve seen them for a long time” (Shane FG2). They acknowledged the scientists' generosity of time and attention, “They take up some of their time to be with us to teach us some more things” (Lisa FG3). The students recognised that the scientists were taking time out from their adult commitments in order to be with the students. The scientists’ prioritising of time in favour of the students made the students feel important and valued by the scientists.

Students felt safe and secure in the knowledge that the scientists would protect them from any possible harm, especially since the scientists often demonstrated activities first:

> We trusted them. When we’re putting the bubbles on, and lighting them on fire I knew it was safe ‘cause scientists wouldn’t lie about…they wouldn’t light you on fire on purpose…I know I can trust them, ‘cause he did it first to show us that it was safe (Peter, FG2).

Etymologically, pedagogy has its origins in the Greek meaning to lead and tend the child in one’s guardianship (Smith, 2012). The adult uses their life experiences to help the child, “Leading means going first and in going first you can trust me, for I have tested the ice. I have lived” (van Manen, 1991b, p. 38). In the same way the parent is concerned with the care and welfare of the child, similarly the teacher, *in loco parentis,* leads the child offering guidance, support and protection:

> Although my going first is no guarantee of success for you (because the world is not without risks and dangers), in the pedagogical relationship there is a more fundamental guarantee: No matter what, I am here. And you can count on me (van Manen, 1991b, p. 38).

The student-scientist trust relationship was more than a “leader-follower relation” (Henriksson, 2012, p. 123). It was also a reciprocal relationship whereby the students considered the scientists trusted them, particularly when participating in what the students perceived to be dangerous activities, “They were like being really nice to us, and they’d let us have a go at it, even though it could be a little dangerous” (Tom, FG3). This atmosphere of reciprocal trust encourages the development of the child’s self-belief. When they sense the adult trusts them, children develop a trust in themselves which builds their self-belief and confidence to attempt new things. Lisa verbalised the students’ developing self-confidence in their ability, “ cause they [the scientists] can trust us … We can do things with chemicals and we know not to eat anything, or put anything in, unless we are told we’re allowed. We can do it ourselves” (FG3). Reciprocal trust is empowering for students because, “children who experience our trust are thereby encouraged to have trust in themselves. Trust enables!” (van Manen, 1991b, p. 68).

Furthermore, a reciprocal relationship of trust can engender a positive, relaxed, open learning atmosphere between the students and teachers, where students feel more relaxed and comfortable to make errors, admit a lack of knowledge, or ask questions of the scientists during the lessons (Frymier & Houser, 2000; Hattie, 2012). Maree, the student who was embarrassed by her mistakes and lack of knowledge in phase 1 of the programme, acknowledged by phase 3 that the programme offered her the, “opportunity to ask all different questions” (Maree, FG3). This illustrates the rapport and trust between students and scientists which accepts that errors and not knowing information is an important part of the learning process. Within this climate of trust the students felt secure and confident to open themselves up to the influences of the scientists. Consequently, the students were able to concentrate on the learning as opposed to self-protection strategies.

4.1.2.1.2 Humour

Humour can be used as a communicating tool to create connections and enhance relationships within a social group (Olsson, Backe, Sörensen, & Koch, 2002). This type of interpersonal humour, often referred to as affiliative humour, is non-derogatory, respectful, and accepting of self and others (Martin, Puhlik-Doris, Larsen, Gray & Weir, 2003). Affiliative humour aids effective group communication and social relationships in a non-confrontational way (Stieger, Formann & Burger, 2011). Individuals who use this type of humour attempt to amuse others by joking and saying funny things, often about themselves (Martin et al., 2003). In the context of this study, affiliative humour can be effective in assisting the establishment of a relaxed, open student-teacher relationship conducive to a positive learning classroom environment.

Several students commented that not only were the scientists fun to be with, they also had a sense of humour which the students appreciated, “they’re really funny sometimes” (Lisa, FG2); “they’re funny… they talk funny and they say funny things” (Maree, FG3); “they’re really funny” (John, FG3). This positive humour can help in developing and “maintaining a relaxed, friendly, open, sympathetic atmosphere between teacher and students” (van Manen, 1991b, p. 202). It has the potential to help break down any possible power imbalances between students and the scientists which might cause anxiety or reticience on the part of the students to participate in science activities.

The students were aware that the scientists did not seem to take themselves too seriously, but were able to relax, let their inner childhood persona appear, and play with the children just like another child, “Yeah, I like Gary. When we were playing cricket out with the scientists we were running after him and he acted like he was a caveman” (Peter, FG3). This assured the students that the scientists were people just like them, who enjoyed games and having fun. It helped to reduce any tensions or anxiety the students might feel around the scientists, resulting in the students feeling relaxed and at ease with the scientists.

Lisa acknowledged the enjoyment and pleasure experienced by the students during the cricket match:

> They’re fun, and funny. Because one of them, we (laughs) we played this cricket with all of them and they versed us in cricket and at the end, we were chasing one of the [Chemistry] Outreach Team and… we were tackling him (FG3).

The opportunity to relax, laugh, and have fun together can engender a social cohesion within the group (Stebbing, 2012). This shared experience creates feelings of friendliness, supportiveness, solidarity, and trust within the group which helps students to develop a constructive attitude towards any mistakes they may make as Lisa explains:

> Mmm, they're really nice and funny. If you muck up they don't tell you off or anything. They just say, oh we could do it again … and they have enough tools to do it twice if we need too, if we muck up (FG3).

This friendly, caring, understanding and trustful climate where students do not feel threatened if they 'muck it up' is conducive to students being more willing to give activities a go, take a risk and go out of their comfort zone in order to challenge themselves in their learning. This was beneficial for the students' learning as it gave them the confidence to challenge themselves in their learning, and take risks even if it meant they might make mistakes. Instead of the students' energies being diverted by feelings of anxiety or reticience to participate, they were more interested and focused on the learning.

4.1.3. Discussion of Attitude Results

This study investigated the students attitudes towards science before, during, and at the end of the Chemistry Outreach programme, thereby establishing any attitudinal changes over time as well as in which phase of the programme these changes occcurred. By phase 2, every student spoke of a positive emotional connection with the science programme. These feelings were not necessarily outwardly observable, but more part of the internalized journey the students were undergoing. There were many differing routes taken by the individual students with regard to their emotional connectedness with the science programme, highlighting the individualised response to science learning. The findings support the research literature that acknowledges attitude is not a static, fixed concept but is predisposed to change over time (Ajzen, 2001; Wilson et al., 2000) and is a highly personalised response to the learning situation (van Manen, 1991b).

Previous research studies involving science initiative programmes have used a comparative approach where attitudes are examined at the end of the programme and then compared to the school science the students experienced prior to the programme under investigation (see for example Forbes, 2014). This study has taken a unique approach by establishing the students' attitudes to science before the programme and tracking the attitudinal changes, if any, over time. Such an approach affords the opportunity to specifically identify when changes in attitude occur and the possible influencing factors. It was noticeable that the students who changed from negative to more positive emotions experienced this transition very early on in the programme, either during the scientists' second visit in phase 1 or the beginning of phase 2. From the second visit the students positive attitudes increased alongside their increasingly more active hands-on role. These findings are consistent with previous research literature which indicates practical hands-on science activites are influential in promoting positive attitudes towards science (Braund & Driver, 2005; Swarat et al., 2012).

The interpreted findings revealed that it was much more than practical science activities that influenced students' attitudes. The students' voices, both written and spoken, as they described the experience in their own words, revealed underlying influences that had the potential to change their attitudes towards science during the programme. These influences related to first, the emotional connectedness with the subject matter, that is the Chemistry Outreach programme, and second, the relational connectedness with the people, that is the scientists. Consequently, the students' favourable responses to the Chemistry Outreach programme can be viewed as a direct result of the scientists as teachers and the learning environment they created.

Factors that influenced the students' attitudes towards the Chemistry Outreach programme included the scientists' passion for science, a climate that accepted errors, the positive power of peers, reciprocal relationships, trust, and humour all helped to forge the students' positive emotional connections with the science programme. Each of these influences are now discussed with reference to the relevant research literature.

The students saw the scientists were passionate about science and wanted to share this passion with the students. From the students' perspective, the scientists did science, were science and lived science. As a result they were great role models for the students. The enthusiasm of the science teacher helps to make science fun and enjoyable and can help students' motivation and the positive way they view science education (Darby, 2005; Logan & Skamp, 2012; Palmer, 2007). Students realised that the scientists accepted errors as part of the learning process, and this helped eased the tension between what the students knew and what they did not know (Frymier & Houser, 2000; Hattie, 2012). Furthermore, their peers along with the scientists, provided emotional support and encouragement when faced with unknown situations. This correlates to research literature that emphasises the importance of positive and supportive learning environments in reducing student internal insecurities, such as their perceived inability in science and the difficulty of science, thereby helping to develop more positive attitudes towards science (den Brok, Fisher & Scott, 2005; Hattie, 2012; Osborne et al. 2003; Wilkinson et al., 2002).

Several themes related to interpersonal connectedness emerged, namely reciprocal relationships, trust and humour. The students believed the scientists would be self-absorbed in science to the detriment of the formation of any positive personal relationships. Furthermore, they imagined the scientists would constantly talk about science in a smart, nerdy manner that would alienate the students from not only the scientists but also from science. The reality for the students was very different from what they had envisaged. They discovered that the scientists were nice people, who were interesting and fun to be with. Moreover, they were closer than expected to their age which the students attributed to helping develop a rapport and understanding between them and the scientists. The students felt the scientists were interested in making strong personal connections with them as unique individuals, not as simply a class of science students. Relationships are an essential part of the educational experience, and good relationships between student and teacher can greatly add to the classroom atmosphere thereby helping in the development of positive attitudes (Gibbs, 2006; Giles et al., 2012).

Furthermore, this personal connection was regarded as more than an adult to student relationship. It was also a reciprocal relationship whereby the students considered they got to know the scientists as people. The fact the scientists were prepared to enter into the students' competitive sports culture by participating in a cricket match impressed the students greatly, and helped to diminish any possible adult /child power imbalance. The students placed great importance on their personal relationships with the scientists as, "students tend to experience instructional relations as personal relations. It matters to them how they matter to their teachers" (van Manen, 1999, p. 23). Through these reciprocal interpersonal connections, the students felt more connected to the scientists and as a result it helped the students to make positive connections with the subject matter the scientists presented.

One anomaly did arise with Jerry who considered he was making friends with one of the scientists. He considered the shared experiences of science and the cricket match formed a basis for friendship. This is contrary to the research findings that indicate students prefer teachers to be friendly with them, but not to become their friends (Henriksson, 2008).

The students highlighted several aspects of trusting in their relationships with the scientists. The students recognised the expertise of the scientists, which lead them to trust the scientists' judgements in relation to the subject content. Scientists as mentors are perceived to be real, authentic and therefore more believable than the classroom teacher (Forbes, 2014). The scientists not only supported the students academically but also nurtured their well-being as well. From the students' perspective, the scientists showed that they were willing to make connections with them. The students could see that the scientists cared enough about them to volunteer their personal time to come and work with them. This engendered a feeling of self-belief for the students knowing that the scientists believed in them and were therefore willing to commit to them (Henriksson, 2012; van Manen, 1991b). Moreover, the students perceived the scientists acted in the students' best interests by demonstrating the safe way to proceed with activities, establishing an atosphere of security (Smith, 2012; van Manen, 1991b). Trust has been associated with improved student capacity to develop positive attitudes towards the subject matter and therefore to learn (Hattie, 2012; Nuthall, 2007; van Manen, 1991b). This atmosphere of trust enabled the student to feel relaxed and comfortable with the scientists. Consequently, the students learned not to feel threatened or embarrassed when they made errors, admitted lack of knowledge, or asked questions of the scientists. This climate of trust encouraged the students to feel secure and confident and this made them more willing to be receptive to the scientists. As a result, the students felt they could concentrate on the learning as opposed to focusing on self-protection strategies.

The scientists' use of humour helped to break down possible feelings of power inbalances between the children and the adults (Olsson et al., 2002). As a result, the students felt relaxed and comfortable in the scientists' company and helped create an open, friendly and supportive classroom climate. This benefitted the students' learning as they were more confident to challenge themselves and take risks even if there was a chance they might make mistakes. Consequently, instead of being distracted, experiencing feelings of anxiety or reticience to participate, the students were more interested and focused on the learning. The use of humour has been found to be conducive to establishing a classroom atmosphere that helps develop positive attitudes (Martin et al., 2003; Palmer, 2007).

These findings resonate with research literature that emphasise the importance of strong, positive student-teacher relationships and supportive learning environments to enhance students' positive attitudes towards science (Darby, 2005; Osborne et al., 2003; Palmer, 2007; van Manen, 1991b). The students in this study are sending a clear message of the important role teachers, in this case scientists, play in establishing strong emotional and relational connectedness with students to help develop the students' positive attitudes towards science. This highlights the characteristics of the interpersonal interaction between students and teachers that is at the heart of effective teaching (Darby, 2005). Furthermore, the students provided practical examples of the scientists' pedagogy that drew the students' attention off their insecurities about their abilities in science and perceived difficulty of science as a curriculum area, and brought their focus back onto the learning and enjoyment of science.

Phenomenology sees learning as integrating the heart (feelings), the hand (actions) and the head (thinking) (Henrikkson & Friesen, 2012). The exploration of the students' affective responses, or feelings which involve the heart have revealed their attitudes towards the science programme. The following examines the students' behavioural responses, or actions which involve the hands, to indicate their engagement with the science programme.

4.2 Engagement

This section explores the influence of a science initiative programme on students' engagement with science education. As outlined in the Literature Review (see 2.2.1), the definition of engagement with school science used within the context of this present study is confined to the behavioural aspect. Behavioural engagement refers to aspects of the students' participation, persistence, effort and/or attention in relation to the subject matter (Capella et al., 2013; Fredricks et al., 2004). The focus in this study is on two behavioural responses of engagement with science education, specifically the social and individual reponses. The social response investigates the students' task engagement within the context of group science activities. Individual responses reveal the students' personal revelations as to their engagement with school science. This involves their short-term engagement, as evidenced in their personal response to the Chemistry Outreach programme, as well as their perceptions of long-term engagement as indicated through the students' predictions of whether they would choose to continue science education at the post primary level.

Data to examine student engagement with science activities were collected through two videos of the children involved in group science experiments. The first video took place before the scientists visited. It involved a National Education Monitoring Project (NEMP) Access Task (Crooks, Smith, & Flockton, 2008) where the students worked as a team to design a fair test experiment involving the dissolving rates of jelly crystals (see Appendix D). The task was administered according to the NEMP specifications. The students were asked to design a fair test to find out if jelly crystals dissolve faster in hot or cold water. They were reminded that in a fair test only one thing is changed at a time and an example of a change of variable was given, for example the temperature of the water. They were informed they could use the equipment on the table which included two boxes of jelly crystals (purple and red); a jug of hot water; a jug of cold water; two plastic glasses; two teaspoons; a recording sheet and stopwatch. At the end of the session they were asked to discuss what they had found out.

The second video, which took place twelve months later during phase 3, was also a group task where the children observed the results of increasing the amount of water with hydrochloric acid on magnesium tape (see Appendix E). The children were given written instructions with diagrams. They were required to replicate three tests using three different concentrations of water and acid, for a total of nine tests. At the end of the session they had two questions to answer: What happened when you added more water? What is the water doing?

In both the jelly crystal activity and the magnesium tape activity I was teaching in the same room but not directly supervising the activity. Data gathered from these tasks were not so much concerned with the accuracy of the students' comments, or with the contexts of fair testing with jelly crystals, and the action of acid and water on magnesium tape, but more with the observable student behaviours of engagement, in particular student talk relating to the scientific task.

4.2.1 Task Engagement

Task engagement refers to the students' involvement in the learning task. It includes observable behaviours such as participation in the task, effort to execute the task, sustained attention during the period of the task execution, persistence in task completion despite distractions, making observations, and discussing aspects of the task with the group (Andersson & Bergman, 2011; Capella et al, 2013; Fredricks et al, 2004).

The analysis of the data sourced from the two videos focused predominately on the students' utterances as an indication of their engagement with the science task. An utterance is defined within the context of this study as a unit of speech ranging from a word to several sentences that are spoken in a block (Allan, 2014). The purpose of an utterance is to communicate meaning from the speaker to the listener and therefore is a socially contructed event that occurs within the constraints of space and time (Allan, 2014). The analysis focused on the frequency of utterances, the type of utterance, and the social interaction indicated through the utterances that could affect engagement. The different types of utterances under consideration included procedural talk, observations, predictions, explanations, and off-task talk. Off-task talk consisted of utterances that did not relate to the science activity at hand (Bragg, 2012), for instance, asking what the other children in the class were doing. A further category labelled 'other' included silence fillers, for example, 'ums,' and incomplete phrases where it was difficult to decipher the speakers' intended meaning.

4.2.1.1 Group A Jelly Crystal Fair Test Activity: Kelly, Lisa, Shane, Malcolm[9]

Kelly, Lisa and Shane gave the impression they were on-task for the 11 minutes 52 seconds it took to complete this activity (see Appendix X). They were all involved in the actual physical aspects of the activity such as measuring and pouring liquids. Furthermore, they all actively participated verbally with Shane contributing 35% to the total student talk, Lisa 27% and Kelly 21% (see Table 2).

Name	Number of utterances per stage	Total Utterances	% of total student talk	Type of Utterance					
				Procedure	Observation	Prediction	Explanation	Off-task	Other
Kelly	4/15/6	25	21%	19	3	1	1	0	1
Lisa	6/21/5	32	27%	25	0	0	0	0	7
Shane	8/18/15	41	35%	18	2	3	1	11	6
Malcolm	3/14/3	20	17%	10	0	0	0	3	7
Total	21/68/29	118	100%	72	5	4	2	14	21

Table 2: Group A Jelly Crystal Fair Test Activity Student Utterances

[9] Not long after this activity, Malcolm left this school, therefore his data is only used when it affects the responses of the other students,

Shane dominated the planning stage contributing 38% of the total utterances, double the number of utterances than Kelly (19%) and a third more than Lisa (29%). This pattern was not so pronounced in the hands-on stage with Lisa contributing 31%, Shane 26% and Kelly 22% of the total student talk. Shane dominated the discussion time at the end of the activity contributing 52% to the overall student talk, which was over double Kelly's (21%) and Lisa's (17%) contributions.

This could lead one to conclude that these students, in particular Shane, were highly engaged as a group in the science activity. However, further investigations of the individual students' types of utterances reveal a different picture. The majority of the students' utterances focused on the task procedures (Lisa 78%; Kelly 76%; Shane 44%), and less than 1% were predictions (Shane 0.7%; Kelly 0.4%; Lisa 0%) and explanations (Kelly 0.4%; Shane 0.2%; Lisa 0%). Observations ranged from 12% (Kelly) to 5% (Shane) to 0% (Lisa). It is very noticeable that Lisa made only procedural comments with no predictions, explanations or observations. Moreover, Kelly and Lisa did not participate in any off-task utterances unlike Shane whose off-task comments contributed to 27% of his total utterances. The link between Lisa's predominance of task procedure utterances and Shane's off-task talk will now be explored further.

During the planning stage, which lasted 5 minutes 11 seconds, Kelly, Lisa and Shane's talk was entirely focused on the science task. They worked well together as a team, with all students participating in the planning, discussing their different role responsibilities, taking turns to offer ideas and listening to others' contributions. Furthermore, all the students contributed to the discussion time at the conclusion of the activity, which lasted 3 minutes 36 seconds. In contrast, during the hands-on activity stage, the group's social interaction patterns changed significantly. Lisa and Kelly maintained on-task behaviours throughout this whole time period of 3 minutes 5 seconds, despite the distractions caused by Shane. These distractions were predominantly managed by Lisa in an effort to keep Shane on-task and following the group's agreed plan. Assuming the role to personally monitor Shane's involvement dominated Lisa's participation in the activity with the result that 50% of Lisa's utterances were focused on controlling, directing and rebuking

Shane in relation to following the agreed procedures. This explains Lisa's dominance of the task procedure talk during the hands-on activity stage. It is of note that for most of the duration of the research period the entire Year 4 cohort of students consisted of Kelly, Lisa, and Shane. They all started this school at age five and knew each other very well from both school and out of school experiences. Consequently, Lisa and Kelly were aware that Shane could be predisposed towards off-task behaviour during classroom activities.

Lisa's micro-management of Shane commenced 13 seconds into the hands-on activity stage when she advised him not to put the jelly crystals into the container until Malcolm and Kelly were ready. Shane made an off-task comment but Kelly immediately brought the focus back on the task by asking if they both have the same amount in their containers.

Lisa: Shane don't put it in yet; wait till they're finished.
Shane: Can I taste it? It looks nice. [Laughing].
Kelly: You guys, do you have the same amount?

Lisa continued her self-appointed responsibility to ensure the smooth running of the activity with particular emphasis on the appropriateness of Shane's actions and comments. This included urging Shane to hurry up when undertaking tasks, keeping him to the agreed plan of action, ensuring he made correct measurements and chastising him when he participated in an improper manner such as throwing jelly crystals at the container. In each of these cases, Kelly supported Lisa as illustrated in the following example when Shane indicated a change to the group's agreed procedure:

Shane: Now I reckon we should tip the water …
Lisa: No, Shane, No, Shane! No! No!
Kelly: Just leave it for now.

Lisa's frustrations showed during the discussion time at the end of the activity when she complained Shane had mixed hot and cold water together instead of using only hot water as the group had agreed upon in the planning stage. She protested "Shane, I told you not to use both " to which he replied "Oh!" and laughed, eliciting an exasperated "Gee!" from Lisa.

Interestingly, when the group was asked whether they would now do anything differently if they had to repeat the experiment, Shane dominated the discussion detailing the procedures that the group had agreed upon during the planning stage. This indicates that there is a strong possibility that Shane was probably aware of the correct procedures throughout the duration of the experiment but chose not to necessarily follow them possibly in response to the way Lisa attempted to control his participation. Consequently, his engagement in the task was compromised not by his ability or willingness to participate but the resulting power struggle initiated by Lisa as she attempted to manage and constrain his behaviours. Lisa attempted to normalize his actions in a way that she considered appropriate for the group and Shane resolved this tension of power by not conforming to her restraints but by participating in off-task behaviours.

4.2.1.2 Group B Jelly Crystal Fair Test Activity: Peter, Maree, Ken and Hayden[10]

Out of all the members of Group B, Ken and Maree displayed on-task behaviours throughout the majority of the task indicating they were behaviourally engaged with the science activity for almost all the 28 minutes it took to complete the task. They dominated the student talk in all the phases of the activity (see Table 3). Over 80% of their utterances focused on the task procedures (Maree 81%; Ken 87%), at least 5% were observations (Maree 6%; Ken 5%), less than 10% were predictions (Maree 9%; Ken 4%) and less than 1% were explanations (Maree 0.01%; Ken 0.06%). Maree did not initiate any off-task talk, whereas after 19 minutes of the activity, Ken did query where the rest of the children in the class had gone. Both Maree and Ken continued a conversation that was initiated by off-task talk by Peter. When Peter suggested the jelly solution looked

[10] Hayden did not remain at this school for the duration of the Chemistry Outreach programme, therefore his data is only used when it affects the other students' responses.

tasty, Maree agreed. Ken was of the same opinion indicating he was keen to taste it. Then the talk immediately returned to the task at hand, with Maree and Ken discussing whether they should stop stirring so they could observe the action of the water on the jelly crystals.

Name	Number of utterances per stage	Total Utterances	% of total student talk	Type of Utterance					
				Procedure	Observation	Prediction	Explanation	Off-task	Other
Peter	5/60/3	68	12%	48	3	0	0	12	5
Maree	20/175/10	205	37%	167	12	18	2	1	5
Ken	12/145/6	163	30%	142	9	6	1	2	3
Hayden	1/112/4	117	21%	91	9	2	3	4	8
Total	38/492/23	553	100%	448	33	26	6	19	21

Table 3: Group B Jelly Crystal Fair Test Activity Student Utterances

Of particular interest throughout this activity was Peter's task behaviour. Peter is a very capable student, particularly in mathematics and science, and he is also very successful in a range of competitive sports. His classmates hold him in high esteem because of his academic and sporting prowess. He always participates well in class discussions making thoughtful, relevant contributions. However, this was not evident during this science activity with comparisons of the total amount of student talk revealing that Peter spoke only a third as often as Maree and half as often as Ken. He contributed only 12% to the total student talk compared to Maree (37%) and Ken (30%). Analysis of his total utterances show a dominance of task procedure comments (71%) with observations totalling 4%. Interestingly, he made 12 off-task utterances which equated to 18% of his total utterances. This unexpected behaviour pattern could possibly be explained by investigating further the peer interactions during this group activity particularly during the planning stage.

During the planning stage which lasted 6 minutes 1 second Peter made five contributions, speaking only a quarter as often as Maree and less than half as often as Ken. Closer examination of this stage shows an emerging pattern whereby Peter deferred to the younger Ken's dominance. This began 1 minute 41 seconds into the planning stage when Ken talked over the top of Peter's first suggestion and continued his discussion with Maree thereby effectively dismissing Peter's contribution.

Ken: (And then after) we've tested both hot or cold we could do luke warm…
Peter: No, we could like count in our heads …
Ken: (talking over Peter) Just mix hot and cold water for luke-warm…
Maree: We want to make it warm?

Peter was aware that the group task was to find out if jelly crystals dissolve faster in hot or cold water and his suggestion offered a possible strategy to calculate the time. In contrast, Ken and Maree were sidetracked by considering the possibility of using luke-warm water.

Ken and Maree constantly maintained eye contact with each other, and continued to acknowledge and build on their ideas, with no opportunity for input from Peter. These actions effectively conveyed to Peter both physically and verbally that he was excluded from participating in the planning discussion. Over a minute later, Maree made eye contact with the other group members and then invited them to make a contribution. By this stage, Peter displayed a readiness to passively comply with Ken's ideas.

Maree: What do you guys reckon?
Peter: I haven't got anything.
Hayden: Me neither …
Maree: Okay, well maybe we could do it Ken's way and see what happens.
Peter: Ken's way.

Throughout the hands-on stage which lasted 20 minutes 27 seconds, Peter was actively involved with the task, assisting with the measuring of the crystals, pouring of the water and using the timer. However, this stage was interspersed with Peter's off-task behaviours, beginning after 2 minutes 27 seconds into the stage with Peter's comment about the jelly crystal looking tasty. He then remarked on how big the teaspoon looked in the water (3 minutes 47 seconds), pretended to lick the spoon (7 minutes 14 seconds), jokingly told Maree to be patient (10 minutes 9 seconds), and ate some spilt jelly crystals off the table (13 minutes 29 seconds) admitting over a minute later that he could not help himself when it came to eating the jelly crystals (14 minutes 56 seconds).

In addition, Peter displayed three instances where he gave up on an aspect of the task, with two occasions when Ken took over the task from Peter. First, Peter gave up the recording role, even though the rest of the group were prompting him as to what to record. Ken took over this responsibility (5 minutes 31 seconds). Five minutes later Peter complained about having to stir the mixture and told Ken that he could do that task. Peter and Ken swapped roles with Peter doing the recording and Ken the stirring (10 minutes 31 seconds).

Peter's lack of persistence with the task indicates he was both mentally and physically acquiescing to Ken's dominance. Even when Ken invited Peter to stir, he declined indicating he could not do it that long and offering the job to Hayden (13 minutes 9 seconds). This increasing self-doubt in his ability to perform physical aspects of the task culminated in his self-deprecating remark when Hayden was pouring water into the container, "you don't want to spill it like clumsy me" (16 minutes). This was despite earlier in the session successfully completing measuring and pouring activities. During discussion time at end of the activity lasting 1 minute 34 seconds, Peter acknowledged along with the other group members that he enjoyed the task but did not share any of his observations or recall of the procedure.

Although this group gave the outward impression during the hands-on stage that all members were actively involved in the task, examination of the student talk revealed that similar to the other two stages of the task, Peter's engagement was compromised. This was not due to his lack of ability but by the social roles enacted by two of the group members, namely Ken and Maree. Throughout the activity, Ken and Maree controlled not only the pace and direction of the activity, but also Peter's engagement with the task. Ken in particular at times acted as a gatekeeper controlling when Peter could participate verbally and physically. This resulted in a power struggle with Peter resolving this tension by acquiescing to Ken's dominance and participating in off-task talk. Overall, Peter's self confidence was affected and consequently his enagement with the task was compromised.

4.2.1.3 Group C Jelly Crystal Fair Test Activity: Tom, Jerry, John, Christopher[11]

This group took 22 minutes 7 seconds to complete this task. They were actively involved in the completion of the task and worked together in a collegial manner. All the group members participated verbally during the activity with John contributing 32%, Tom 29% and Jerry 28% to the total student talk (see Table 4).

Name	Number of utterances per stage	Total Utterances	% of total student talk	Type of Utterance					
				Procedure	Observation	Prediction	Explanation	Off-task	Other
Tom	14/59/5	78	29%	64	7	2	0	1	4
Jerry	6/58/9	73	28%	48	17	1	4	0	3
John	9/73/4	86	32%	61	15	1	6	0	3
Christopher	1/26/1	28	11%	22	5	0	0	0	1
Total	30/216/19	265	100%	195	44	4	10	1	11

Table 4: Group C Jelly Crystal Fair Test Activity Student Utterances

During the planning stage, which took 4 minutes 22 seconds, Tom dominated the student talk contributing 47% of the total utterances. This was over double the number of utterances than Jerry (20%), and a third more than John who contributed 30% of the total utterances. However, this pattern did not continue for the rest of the activity. During the hands-on stage, which lasted 15 minutes 52 seconds, John spoke more (34%) with both

[11] As Christopher did not remain at this school for the entire duration of the Outreach programme his data is only used when it affects the other students' responses.

Tom and Jerry contributing 27% to the student talk. Jerry dominated the 1 minute 52 second discussion time at the end of the activity contributing 47% to the overall student talk, which was over double Tom's (26%) and John's (21%) contribution. Over 65% of their utterances focused on the task procedures (Tom 82%; John 71%; Jerry 66%), at least 9% were observations (Jerry 23%; John 15%; Tom 9%), less than 4% were predictions (Tom 3%; Jerry 1%; John 1%) and less than 8% were explanations (John 7%; Jerry 5%; Tom 0%).

Only one off-task utterance occurred during the entire session. This came 17 minutes into the activity, when Jerry encouraged John to add more jelly crystals to the solution.

Jerry: Add more John.
Tom: Yeah. Stop, stop, stop. It's gonna be too full.
Jerry: John!
John: [laughing].
Jerry: Oh, yah, my gosh!
Tom: I swear if he were a scientist, they'd kick him out. Now we'll just leave them for a couple of minutes to see what happens.
John: OK, how many minutes, about two. About two minutes? Two minutes, yeah.

Immediately after making the remark about John being kicked out, Tom spoke about the next stage of the activity indicating that he was back on-task. Likewise, John's next response was on-task indicating he was not distracted or offended by Tom's comment and probably took it as light-hearted banter.

Overall, it would seem that this group demonstrated engagement with the task, with all members participating through talk and action, persisting with the task until completion and attending to the task throughout the session. However, it is of note that John requested not to be part of the group with Tom and Jerry when they did the magnesium tape experiment. Did this indicate that subconsciously he felt that he was not able to engage with the science activity to the degree he felt he was capable of if he continued to work with these group members? Was there some degree of internalised power tension for John with his peers that was not apparent through his actions and behaviours? The answers to these questions are outside the realm of this study due to the internalized aspect of these behaviours. However, John's degree of engagement within his self-selected group can be compared with the teacher-selected group.

4.2.1.4 Magnesium Tape Experiments

Six months later the children participated in group science experiments involving dissolving magnesium tape in different concentrations of hydrochloric acid. Changes within the composition of each group are indicated at the beginning of each analysis. It is of note that the grouping for the magnesium experiments ended up corresponding to the children's year groups. The time for the groups to complete this experiment ranged from 64 to 78 minutes due to the accuracy required in the measuring tasks. This is much longer than the jelly crystal activity where the groups took from 11 minutes to 28 minutes to complete the task.

4.2.1.4.1 Group A Magnesium Tape Activity: Kelly, Lisa, Shane

The composition of this group differed from the initial jelly crystal as Malcolm was no longer at school. The group took 78 minutes 4 seconds to complete this task. The task involved reading the instructions and deciding on roles (1 minute 30 seconds), the hands-on activity stage comprising two sessions (53 minutes and 22 minutes 19 seconds totaling 75 minutes 19 seconds) and the discussion of the questions (1 minute 15 seconds).

All group members participated with Shane contributing 42% to the total student talk, Lisa 33% and Kelly 25% (see Table 5). Although Lisa dominated the planning stage with 44% of the total student utterances compared to Shane (31%) and Kelly (25%), it was Shane who contributed the most during the hands-on and the final discussion stages. He contributed 42% to the total student talk during the hands-on activity and 58% during the final discussion compared to Lisa (32% and 37% respectively) and Kelly (26% and 5%

respectively). Over 83% of their utterances focused on the task procedures (Kelly 89%; Lisa 89%; Shane 84%), at least 6% were observations (Kelly 6%; Shane 6%; Lisa 5%) with less than 1% predictions (Shane 0.09%; Lisa 0.07%; Kelly 0.03%) and less than 3% were explanations (Shane 2%; Lisa 1%; Kelly 1%).

Name	Number of utterances per stage	Total Utterances	% of total student talk	Type of Utterance					
				Procedure	Observation	Prediction	Explanation	Off-task	Other
Kelly	4/188/1	293	25%	261	20	1	3	1	7
Lisa	7/369/7	383	33%	342	21	3	7	3	7
Shane	5/472/11	488	42%	408	33	4	10	11	22
Total	16/1129/19	1164	100%	1011	74	8	20	15	36

Table 5: Group A Magnesium Tape Activity Student Utterances

Off-task talk amounted to 1% of the total utterances with Shane dominating this type of comment. However, the participation in off-task talk did not lead to off-task behaviours. The talk was often light-hearted banter as illustrated by Shane encouraging Kelly to move her head so he could see the experiment better, “ Move your big swede, no offence” whereupon Kelly immediately replied, “OK and that’s one more [test] to go.” It would seem Kelly did not take offence with this comment and remained on-task. When Shane was distracted by the teacher’s stamp on the table, he commented, “Look, I’ve got Mrs John’s[12] stamp. She left it here.” Lisa acknowledged his comment and immediately brought him back on task “Yeah, she does. Just leave it there.” Shane immediately came back on task, helping with the accurate measuring of the liquid. This is in direct contrast to the controlling, directing and rebuking of Shane that occurred during the jelly crystal activity. Instead the social interaction during the magnesium tape experiment seemed more inclusive, relaxed and supportive of Shane. When Shane was frustrated with himself after he accidentally knocked over the test tube, “Why do I keep on doing that … I’m not trying to be stupid,” both Lisa and Kelly reassured him.

[12] Mrs John is a pseudonym

4.2.1.4.1 Group B Magnesium Tape Activity: Maree, John, Ken

The composition of this group differed from the initial jelly crystal activity as John requested to work with Ken, Maree and Christopher because he felt he was always working with Tom and Jerry. This led to John replacing Peter in this group and Peter working with Tom and Jerry. Christopher also elected to work with Ken and Maree with the resulting group now containing all the Year 5 students in the class.

All group members participated during the total 64 minutes 11 seconds taken to complete the task with Maree contributing 34% to the total student talk, John 33% and Ken 25% (see Table 6). It is interesting to note that although the first stage was only 20 seconds in duration, all group members spoke at least once, quickly establishing their roles and demonstrating a desire to get on with the task.

Name	Number of utterances per stage	Total Utterances	% of total student talk	Type of Utterance					
				Procedure	Observation	Prediction	Explanation	Off-task	Other
Ken	1/262/13	276	25%	252	14	8	2	0	0
Maree	2/355/9	366	34%	342	14	6	4	0	0
John	1/355/9	365	33%	331	18	9	3	0	1
Christopher	1/347/14	86	8%	79	4	2	1	0	0
Total	6/1044/40	1090	100%	1004	50	25	10	0	1

Table 6: Group B Magnesium Tape Activity Student Utterances

John and Maree contributed the most during the 61 minutes 16 seconds it took to complete the hands-on stage, both contributing 34% of the total student talk compared to Ken's 25%. In contrast, Ken contributed 33% during the 2 minutes 35 seconds of the final discussion stage, compared to John and Maree's 23%. Over 90% of their utterances focused on the task procedures (Maree 93%; Ken 91%; John 91%), at least 3% were observations (Ken 5%; John 4%; Maree 3%), less than 4% were predictions (Ken 3%; Maree 2%; John 2%) and less than 2% were explanations (Maree 1%; John 0.08%; Ken

0.07%). The students were focused on the task at hand for the duration of the activity, with no off-task comments or behaviours occurring during the 64 minutes of the task.

John's participation as a percentage is similar in this experiment (33%) compared to the jelly crystal activity (32%). However, this translated to 355 on-task utterances over the 64 minute period compared to 83 on-task comments over 22 minutes for the jelly crystal activity. It could therefore be concluded that within this self-selected group, John was more engaged for a longer period of time. Furthermore, he engaged in more prediction comments during the magnesium tape experiment indicating he was thinking more deeply about what was occurring during the experiment.

Of particular interest throughout this activity was Ken's behaviour. Throughout the jelly crystal activity, Ken took a dominant role especially in relation to controlling Peter's engagement both verbally and physically. However, during the magnesium tape experiment, Ken's behaviour was more inclusive as illustrated by his consultation with John, "do you want to put the magnesium tape in and I'll record it?" and his invitation to Maree to seek an explanation, "what do you think the water does to it Maree?" Furthermore, he was supportive of his team members complimenting them as they worked on aspects of the task "Good work, Christopher." Overall, Ken contributed less to the discussion than the other group members but his contributions were thoughtful as he attempted to detail what he had observed and at times tried to explain his observations, "the water was wearing out the acid … it was taking longer [to dissolve] because there's less acid."

4.2.1.4.3 Group C Magnesium Tape Activity: Tom, Jerry, Peter

As indicated, the composition of this group differed from the initial jelly crystal activity with Peter replacing John and Christopher who both choose to work with another group. This resulted in a group consisting of all the Year 6 students in the class.

Tom, Jerry and Peter all participated throughout the duration of the experiment with Peter contributing 41% of the total student talk and Tom and Jerry contributing 32% and 27% respectively during the 70 minutes 33 seconds it took to finish this activity the task (see Table 6). The planning stage was very quick, only 14 seconds, with Peter reading the instructions and delegating Tom a role in measuring. The hands-on activity stage was held over two sessions lasting 28 minutes 36 seconds and 38 minutes 44 seconds totaling 67 minutes and 20 seconds. Peter continued to dominate this stage and the last stage of the activity contributing 41% to the total student talk during the hands-on activity stage and 56% during the 2 minutes 59 seconds of the final discussion compared to Tom (32% and 33% respectively) and Jerry (28% and 15% respectively).

Name	Number of utterances per stage	Total Utterances	% of total student talk	Type of Utterance					
				Procedure	Observation	Prediction	Explanation	Off-task	Other
Tom	1/249/12	262	32%	214	29	9	9	0	1
Jerry	0/217/4	221	27%	183	24	5	4	1	4
Peter	2/317/20	339	41%	302	14	9	10	0	4
Total	3/783/36	822	100%	699	67	23	23	1	9

Table 7: Group C Magnesium Tape Activity Student Utterances

Over 81% of their utterances focused on the task procedures (Peter 89%; Jerry 83%; Tom 82%), at least 11% were observations (Tom 11%; Jerry 11%; Peter 4%), less than 4% were predictions (Tom 3%; Peter 3%; Jerry 2%) and less than 4% were explanations (Tom 3%; Peter 3%; Jerry 2%).

The only instance of off-task talk came 28 minutes into the second hands-on stage when Jerry dropped the pipette and he asked Peter to pick it up, referring to him as "my little slave." Peter acknowledged this little light-hearted banter and immediately returned to the task at hand, "OK. So this is our last test."

Of particular interest is the change in Peter's engagement behaviours as exhibited during the jelly crystal activity. This current experiment was conducted over two sessions with the first session lasting 28 minutes 50 seconds and a considerably longer second session lasting 41 minutes 43 seconds. Although this experiment took significantly longer to complete compared to the jelly crystal activity, it is noticeable that all the participants were engaged throughout the duration of the experiment. Furthermore, Peter dominated the student talk during all the stages of this activity contributing a substantial 41% to the overall total. This is in direct contrast to his engagement during the jelly crystal activity where due to the actions of two of the group members, in particular Ken, Peter only contributed 12% to the student talk.

Analysis revealed the underlying influences of peer relationships, which dramatically affected some students' opportunity to engage with science within a group context. Two types of peer influences were revealed during the jelly crystal activity sessions. The first was discernable through the student talk and behaviours and involved relationships of power. Shane's engagement was compromised by the controlling actions of Lisa and, to a lesser degree, Kelly. Similarly, Peter acquiesced to Ken's, and, at times Maree's dominance of the pace and direction of activity which constrained his ability to engage fully in the activity. Interestingly, these behaviours did not continue into the magnesium tape sessions. Instead, the tone was very inclusive and supportive. This could be attributed to the format of the Chemistry Outreach programme, which involved the students working in cooperative peer or group contexts. Lisa and Maree often showed understanding towards Shane for example reassuring him when he accidentally knocked over some equipment. Ken was likewise more inclusive, consultative and supportive of all his group members. Peter, operating in a self-chosen group, dramatically increased his participation in on-task student talk by nearly four fold compared to his jelly crystal talk.

The second type of peer influence was not evident through either the student talk or the behaviours during the jelly crystal activity. Indeed, it only became apparent during the student and teacher talk prior to the start of the magnesium tape experiment when John requested to work with other children. It was presumed that John subconsciously felt working with Tom and Jerry had in some way compromised his engagement. This could indicate there was an underlying desire to be more engaged with the science activities, which was realized when he worked with his self-selected group.

This section explored the students' engagement with science tasks within a group situation. This was established by exploring the students' talk and behaviours. But, what did the students themselves think about their engagement with science tasks? The next section explores this aspect as described in the students' own words.

4.2.2 Science Education Engagement

The data to examine the students' perceptions of their engagement with science education was collected at the end of the programme specifically through the third focus group interviews and the students' reflective writing. Through the analysis of the data, two predominate behavioural responses of engagement with science education emerged. These involved first, the present engagement with subject matter as demonstrated through the students' reflections of their involvement with the Chemistry Outreach programme, and second, the long-term engagement with school science, evidenced by the students' predictions as to whether or not they would choose to be involved in secondary school science.

4.2.2.1 Present engagement with school science

All the students believed the science initiative programme had helped develop their engagement with science. The students expressed a variety of reasons why the science programme engaged them with school science. These are described below under the sub-themes of: scientists' expertise; authenticity of the programme; and student participation.

4.2.2.1.1 Scientists' expertise

Tom considered he did not really connect with science during his previous experiences of school science, "in the junior room, I don't really understand what they're talking about" (FG3). From Tom's viewpoint, the scientists were almost like an epiphany, "but when the university people came, I kind of got along with science and started to realise what they were saying 'cause they like they know more and they say better words" (FG3). He credits the Chemistry Outreach team with helping him to engage with science due to their specialist knowledge and the way they could explain the concepts to him. Maree also acknowledged the fact the scientists helped her connect with science, attributing the scientists' expertise with the subject matter as the means for them to be able to explain science in a way the students understood, "They explain it better… because they do it more precisely 'cause they know what they're talking about" (FG3). Furthermore, access to the scientists' expertise meant "we've got that opportunity to ask all different questions" (Maree, FG3). John questioned whether the junior room teacher had the same expertise as he believed "she just got it from books, or websites" (FG3). The students attributed their own developing knowledge to the way the scientists used their expertise to explain and clarify scientific concepts and ideas, and were open to the students questioning and discussing their ideas.

4.2.2.1.2 Authenticity of Programme

The students noted that the Chemistry Outreach programme felt more like what they perceived real science to be, in contrast to the science they had experienced before, "in the junior room, science, it's not kind of real like the university science" (Jerry, FG3). They felt that they did not do 'real' science in the junior years because they were younger children. Peter considered the teacher had the control of the activity because in his view younger children did not have the necessary skills, "in the junior room, the teacher was putting all the stuff in 'cause we weren't that careful" (FG3). He believed the teacher demonstrated the experiments due to a perceived weakness on the students' part, namely they were not careful enough to work on the science experiments. For this reason he believed that students were now allowed to do hands-on activities because they are older and hence more careful, “but now that we’re careful in the senior room, the scientists let us do what what we’re doing” (FG3).

The students perceived science with the scientists to be more real “because it’s what real scientists do” (Maree, FG3). They felt the content had not been ‘dumbed down’ because they were children. The students were immensely proud of the fact that they were doing experiments that the scientists had admitted that they not tried before, “when I go to the senior room all this year we were doing experiments that some of them [the scientists] haven’t done before” (Jerry, FG3). Hence, the students felt they were on equal footing with the scientists. The students also felt special because they were aware that, “well, some of the schools they don’t get scientists” (Maree, FG3), and they appreciated the preferential treatment they considered they were receiving from the scientists.

Moreover, they could see that they were capable of collaborating with the scientists, “it’s a real good opportunity to work with those scientists” (Maree, FG3). This working alongside the scientists made them feel very grownup and important, and they felt gave their student-directed community investigations an air of credibility. This collaboration made them realise that they, “can achieve the skills that actual scientists have” like the ability to “respect other people’s ideas” (Kelly, FG3). The theme of collaboration was elaborated on by Shane who explained how the students collaborated together in their experiments and investigations, “now in the senior room we like buddy up with like a few teams, like five in a team and we use things and we did it ourselves. Like everyone would get a turn at something” (FG3). This social participation helped engender feelings of togetherness and a focus of working together to achieve a common goal which is very similar to the structure of a learning community that scientists would participate in.

4.2.2.1.3 Student Participation

The students compared the Chemistry Outreach science to what they had previously experienced in school science. Lisa recalled science when she was younger where, “we used to have to watch the teacher do everything … and we just looked at things from the board, we didn't have heaps of different things to do" (FG3). The ownership of the learning was with the teacher and the children had a somewhat passive role. John implied a transmissive view of teaching and learning where, "the class usually sits on the floor, and the teacher does it while we learn"(FG3). This "banking concept of education" (Freire, 1972, p. 42) tends to portray students as accumulators of knowledge rather than active inquiring participants in the learning process. Kelly lamented the fact that as a group watching a demonstration they missed the opportunity to observe carefully what was going on, "we're all crowded around one table and it's really hard for some of us to see. So some of us don't even get to see, we're just standing there and we're not really learning anything" (FG3). By not getting the opportunity to observe what was going on, the students missed the opportunity to make connections from their observations to their evolving conceptual understandings.

The students preferred the hands-on approach to science offered by the Chemistry Outreach team, "because we're doing it ourselves, we're not watching" (John, FG3). Maree found it to be more enjoyable, preferring to do the activities herself as opposed to watching a teacher demonstration, "when you're watching it gets a wee bit boring, yeah and when you're actually doing it, you're really excited and stuff" (Maree, FG3). She found the hands-on approach to be a more intimate learning environment which resulted in the development of positive emotions and attitude.

The students considered the hands-on approach was more conducive to learning because they were actually doing it. As Ken explains, "We get to do it instead … and we can learn what happens if we do stuff" (FG3). He elaborates "because we get to do it all ourselves … we know what happens, how it works" (FG3). John concurs stating "you learn more when you're doing it" (FG3). Maree agrees, stating this approach leads to a better understanding: "I understand it more. We're doing it ourself" (FG3). She believed it gives them a better opportunity to observe what was actually happening, "we're noticing things… we're noticing everything that's happening while we're doing the experiment" (FG3).

The hands-on approach offered the students an opportunity to be closer to the experiment, therefore closer to the action and hence able to notice more than if they were in a group watching a demonstration. Lisa considered they “can actually learn to do it properly, not just watch someone that can actually do it” (FG3). The students are able to actively participate in the learning process because “ they let us find out for ourselves by doing experiments…to find out information about that thing" (Tom, FG3). They had the opportunity to physically position themselves so they could measure accurately, observe carefully, and they had more control over the pace of the lesson, for instance, by adding things when they were ready.

Furthermore, the students were aware that this approach gave them the opportunity to learn from their mistakes, “if you make a mistake, you learn from it” (Peter, FG3). In essence this means the students have more control and power within the science session knowing that if they perceive that they have done it wrong the first time, they have an opportunity to redo that part of the experiment. I would argue access to this type of student agency is not possible in a demonstration-type science lesson.

4.2.2.2 Long-term engagement with school science

As already discussed, all the students acknowledged they had very positive attitudes towards and engagement with school science by the end of the programme. Furthermore, they were keen to continue with school science, especially with the Chemistry Outreach scientists. One could therefore expect these students would continue to be keen to engage in school science in the short term, namely in primary school. But, can one assume that these predispositions will necessarily lead to these students wanting to continue with school science in the long term? In other words, will these students choose to pursue further science study at secondary school especially once it becomes an optional subject choice in the secondary school curriculum? This next section reveals the range of opinions voiced by the students as to their further involvement in post primary school science, under three sub-themes of definitely decided; on the way to being decided; and undecided.

4.2.2.2.1 Definitely Decided

Ken, Peter, Kelly and Lisa were adamant that given a choice they would continue with science at secondary school. Lisa valued science education viewing it as, “fun and it’s good to learn how science works” (FG3). She appreciated the foundation base of science experienced through Chemistry Outreach regarding it as a platform to develop her skills further, “ it’s good to learn all sorts of new different things and you can learn things that are harder than we did at primary school” (FG3). Peter and Ken enjoyed science and saw the value of learning science to develop their knowledge so they can, “learn some new things about the world” (Ken, FG3). After the initial scientists’ visit Kelly wrote, “I couldn’t wait for the scientists to come back to school and now I wish I could be a scientist one day” (WR3). She linked school science to life-long learning including career aspects, “ because it could help me through my life… like if you’re a farmer” (FG3).

4.2.2.2.2 On the way to being decided

Jerry sounded unsure as to whether he would choose to participate in secondary school science. However, this may be attributed to the fact that he had not yet seen the links between the various strands of science, “Mmm, I’m not that sure, I’m not really a science person. I’m more interested into like making sure all the pests don’t come into our country” (FG3). The Chemistry Outreach programme focused on the Material World strand of *The New Zealand Curriculum* (Ministry of Education, 2007), which develops chemistry knowledge and understandings to help students understand the world around them. Jerry was interested in the Living World strand, which focuses on living things and their interaction with each other and the environment, including aspects such as sustainability and biosecurity. At this stage Jerry had not made the link that learning about the Living World was part of the science curriculum.

Although Shane reported he wanted, “to be a science person” (WR3), initially he thought he might only be involved in secondary science, “maybe a little bit” (FG3). But given the opportunity to think through his reasoning he saw connections with science in his life once he had left school, “cause when you grow up, when you’re like whatever you want to be, in some of those things you’ll need science, like in farming” (FG3). Finally, he concluded, “Yeah, I probably would take science in secondary school, yep” (FG3).

4.2.2.2.3 Undecided

Tom was more reluctant about choosing secondary schooling science. He was initially not looking forward to the scientists coming to school but once he had experienced the programme he indicated his willingness to participate in more science, “I got used to science after a while. I could do it much longer” (WR3). However, he was reluctant to commit himself to secondary school science at this stage, responding with a noncommittal, “maybe” (FG3).

John’s priorities for subject choice at secondary school were influenced by what he perceived to be a weakness in his primary schooling, namely his spelling scores. Therefore, his lifeworld at the moment is focused on improving his spelling ability. John is interested in science but was not ready to commit to long-term engagement, “I might change my mind to not be a scientist” as his immediate priority is elsewhere, “cause I might be busy with like learning… working on my spelling” (FG3). Finally he acknowledged “Maybe, …well I’d be interested in… well probably not that interested but, a bit interested in” (FG3) in pursuing science at the post primary level.

Maree was also leaving her options open as to whether she would take science in secondary school, “yes maybe. … I might. It depends what other activities there are to do” (FG3). She was sure that science would be part of her life whether or not she took it as a post-primary option, “In your own time maybe you could do a few experiments” (FG3). Furthermore, she acknowledged that being a girl would not stop her from taking science as she considered, “girls are just as good as boys” noting that, “last time there were three girls come to do science with us” (FG3).

In summary, all the participating students had a very positive attitude towards and engagement with school science by the end of the programme, leading one to assume they are more likely to participate in secondary school science. When asked whether they would continue with science, the responses were not unanimously in favour of post primary school science. In fact, only two-thirds of the students stated they would choose to take part in school science once it became optional.

Closer investigation of the students' decisions was achieved by comparing the attitudinal change over the duration of the programme with the students' decision to participate in secondary school science (see Table 8). This analysis revealed students who had very positive attitudes towards science from the outset of the programme and continued to be positive throughout the programme all stated they intended to further pursue science at secondary school. It needs to be noted that Shane needed the opportunity to think through his decision before finally concluding that he would take secondary school science.

Student-age	Attitudinal change	Secondary School Decision
Ken - 10 years	Locking in already positive attitudes	Definitely Decided
Kelly - 9 years	Locking in already positive attitudes	Definitely Decided
Peter - 11 years	Positivity tinged with reservations	Definitely Decided
Lisa - 9 years	Positivity tinged with reservations	Definitely Decided
Shane - 9 years	Locking in already positive attitudes	On way to be being decided
Jerry - 12 years	Journeying to positivity.	On way to be being decided
Maree - 10 years	Positivity tinged with reservations	Undecided
John - 10 years	Journeying to positivity.	Undecided
Tom - 12 years	Journeying to positivity.	Undecided

Table 8: Comparison of attitudinal changes over duration of the programme with the decision to participate in secondary school science.

The next group of students was initially positive in their attitude towards school science but their feelings fluctuated during the second phase of the programme before returning to a positive attitude. Two of the three members of this group, Peter and Lisa, were sure they would continue with school science but Maree, although acknowledging science to be part of her life, was unsure whether she would take post primary school science. In the final group of students who were not positive towards science initially but were by the end of the second phase, two were undecided about taking secondary school science. The third student, Jerry, was somewhat confused with what science entailed and seemed unaware that his desire to work with pest control was actually science related. Overall, there were four students who were definitely decided, two students who were on the way to being decided, and three students who were undecided.

Of particular relevance to this study is Murphy and Beggs (2005) findings that students lose interest in science especially after age of 10. Although this group is a small sample, it is interesting to compare results according to age. The three children in this group who were older than 10 (all boys) covered the range of options with their decisions: one 12 year old undecided, one 12 year old on the way to decided and one 11 year old definitely decided. It is relevant to note that all the post 10-year-old students did not start with positive attitudes at the beginning of the Chemistry Outreach programme. One boy's attitude was positive tinged with reservations and he went on to be definite about taking secondary school science. In contrast, the other two boys were both negative to start with and their final decisions regarding further school science were on the way to being decided and undecided. As it is not possible to generalise from this very small sample, the exploration of attitudes and engagement as predictors of long-term engagement with school science could be a possible area for future research.

4.2.3. Discussion of Engagement Results

The first experiment revealed two examples of small group peer relationships having the potential to negatively affect students' ability to engage with science. In the first example, group members used their power to normalize other group members' behaviours, as was evidenced in Lisa's, and to a lesser extent Kelly's controlling of Shane's actions, and Ken and Maree's exclusion of Peter's participation in the first video (Foucault, 1977). Shane's group was more inclusive and supportive of Shane in the second experiment, and Peter, within another group, dramatically increased his participation. The second example occurred when John requested to work with another group for the second experiment, presumably because he felt his engagement was compromised in the first group. John's participation rate increased when he was in his self-selected group for the second experiment. This highlights research findings that show that although teacher selected groups may appear collegial and collaborative, they can be affected by underlying social factors such as the desire to maintain social harmony (Anderson et al., 2008).

These results support research findings that social relationships and task engagement are interlinked (Gristy, 2012; Hattie, 2012; Nuthall, 2007). As small group activities provide more opportunity of peer interactions compared to whole class sessions, there is a strong chance of peer relationships and the status of power within groups affecting individual student's involvement in the task activity (Hattie, 2009).

All the participating students demonstrated increased engagement during the second science group experiment. Even though this second experiment was of much longer duration, the students consistently displayed more on-task behaviours, showed considerable effort in executing the task, demonstrated ongoing attention throughout the period of the task as well as persistence in the task completion. Therefore, over time, there was an increase in more co-operative team working skills resulting in more on task engagement. This was due to the format of the Chemistry Outreach programme, where students worked with self-selected partner or small groups for all the activities. They were not specifically taught how to be supportive, inclusive group members who accepted others' viewpoints, but there was an expectation that they needed to work in a collaborative way, focused on the task at hand, similar to the work of scientists.

Each student indicated they believed the Chemistry Outreach programme helped develop their engagement with science. Through talking about their experiences with the Chemistry Outreach programme factors were revealed which had the potential to positively influence the students' engagement with science. These factors included the scientists' expertise, the authenticity of the programme, and the opportunity to actively participate in the science activities.

As the students acknowledged their appreciation of the scientists' expertise, they revealed aspects of the scientists' "instructional pedagogy" (Darby, 2005, p. 425) that drew them into the learning process and assisted them in developing an understanding of scientific concepts. The students identified the way the scientists used their expertise to explain and clarified scientific ideas and concepts and were receptive to the students asking questions and discussing ideas. Research has shown minds-on activities that include the challenge to think, question, and dicuss ideas resulted in increased student engagement (Bennett & Hogarth, 2009; Bowmar, 1997; Mant et al., 2007). These findings are consistent with other research that explores the value students place on scientists as mentors, and the increase in student engagement with science as a result of the expertise of the scientists (Bolstad & Bull, 2013; Forbes, 2014).

The students perceived the Chemistry Outreach programme to be more authentic or real than what they had previously experienced. They considered they were treated as young scientists capable of scientific investigations within a collaborative context similar to the way scientists work (Forbes, 2014). Research literature indicates students appreciate hearts-on activities that give the student the opportunity to investigate their own questions as it gives them a sense of control and ownership of their learning (Chin & Osborne, 2008). Collaboration and student ownership of scientific investigations have been found to increase student engagement (Forbes, 2014).

The students regarded practical hands-on activities as more conducive to learning because of the active participation, the opportunity to find out things, and the agency to repeat or change parts of the experiment if they considered they had made a mistake. These opportunities had not been present during their previous experiences of demonstration type science lessons. Research has found practical hands-on investigative science is the preferred pedagogical approach in science learning (Abrahams, 2009; Barmby et al., 2008; Skamp, 2007; Swarat et al., 2012), resulting in students being engaged during science activities and wanting to do more science at school (Kerr & Murphy, 2012).

The pedagogical approach of a combination of hands-on, minds-on and hearts-on science experiences (Skamp, 2007) within the Chemistry Outreach programme helped to increase student short-term engagement with science. However, this positive engagement with science may not necessarily always translate into long-term engagement with science. This could be attributed in part to what Abrahams (2009) refers to as "situational interest" (p. 2349) where the student is engaged with the activity or programme in the immediate sense, but this does not necessarily become a predictor of long-term engagement. Four students indicated they would definitely take secondary school science once it was no longer compulsory, and two students were on the way to being decided. The three students who were not ready to definitely commit to secondary school science, did admit to being interested in science, but were keen to be open-minded in case other options should present themselves. The students in the group who were undecided were ten years or older, which is when Murphy and Beggs (2005) found students lose interest in science. This signifies an urgency to involve students prior to the age of ten in school science that not only engages them but also allows them to see the relevancy of science to their own lives and therefore the value of long-term engagement with school science, whether or not they intend to pursue a science career.

These results send a word of caution to those who advocate increased engagement with science, and more positive attitudes towards science as a precursor to long-term engagement with school science. The world can be a complex place for children to navigate and these results show that there is not a direct causal link for all students between a positive attitude and engagement with school science and the choice of future school studies in science. It would seem, therefore, that for these students attitude and engagement were not the only factors affecting their decision whether to select science when they attended secondary school.

This chapter has explored the influence of the Chemistry Outreach programme on the students' attitudes (affective responses or feelings) towards school science, and engagement (behavioural responses or actions) with school science. The following chapter will continue with the phenomenological stance towards learning taken within this study and will explore the students' thinking (cognitive responses) in school science by examining the influence of the Chemistry Outreach programme on the students' use of scientific skills and language.

CHAPTER FIVE
SCIENTIFIC SKILLS AND SCIENTIFIC LANGUAGE

5.0 Introduction

This chapter examines the influence of the Chemistry Outreach programme on the students' use of scientific skills and scientific language. It continues with the phenomenological stance that views learning as involving the heart, hand and head. The previous chapter explored the students' affective responses (feelings which involve the heart), and behavioural responses (actions which involve the hand) towards the Chemistry Outreach programme. This chapter explores the students' competencies with scientific skills as well as the use of scientific language to reveal the students' cognitive responses (thinking which involves the head) towards the Chemistry Outreach programme. The focus is on the process the students experience as they develop their ability and understanding of the scientific skills and language required to conduct scientific investigations.

5.1 Scientific Skills

Scientific skills refer to the skills used during scientific investigations and encompass what scientists do and what they think about when they are engaged in scientific endeavours (Ambross et al., 2014; Feasey, 2012). The focus of this study is on the students' use of scientific skills on the individual level and within the social context of a small group science activity. The individual level investigates the student's self-reporting of their use of scientific skills when conducting a scientific investigation. The social level examines the roles undertaken by students pertaining to procedural and meaning-making skills within a small group science experiment.

5.1.1 Self-reports of scientific skills usage

The data used to explore student confidence in using scientific skills were sourced from the first focus group interview prior to the commencement of the Chemistry Outreach programme and the third focus group interview at the end of the programme. During these interviews the students were asked to identify what they considered they were good at in science. Skills identified by the students were categorized according to what scientists do and what scientists think about, in other words, the doing and thinking skills used by scientists (Feasey, 2012). The doing skills include the use of equipment, measurement, documentation of information, communication of results, risk identification, and risk control (Feasey, 2012). These practical skills, necessary for working scientifically, focus on the procedures required when carrying out science investigations and are referred to in this study as procedural doing skills. Thinking skills (thinking scientifically) can be viewed as the "thinking behind the doing" (Roberts, 2001, p. 114). They involve the knowledge base of ideas and decisions related to the need for scientific evidence to be believable and to be able to withstand scrutiny (Wenham, 2005). This requires the knowledge of "how, why and what that underpins working scientifically" (Feasey, 2012, p. 62) termed as "concepts of evidence" by Gott and Duggan (1995, p. 30). These concepts of evidence are essential in the production of trustworthy and believable scientific data. The use and understanding of the concepts of evidence means students are developing an awareness of the process involved in gaining scientific knowledge, in other words, procedural understandings, as opposed to receiving knowledge from experts, in this case, the scientists.

All participating students considered that they had developed their ability to use a variety of scientific skills during the period of the Chemistry Outreach programme. The analysis of the data identified three sub-themes that described the students' change towards this more confident use of scientific skills. These sub-themes included: none to some skills; general to the precise; and passive to active participation. Furthermore, the way the students talked about the scientific skills they considered they were proficient in revealed a developing understanding of the thinking behind the working scientifically. This is presented according to the ideas and decisions related to the collecting, handling, interpreting and communicating of scientific data (adapted from Feasey, 2012).

5.1.1.1 None to some skills

Three students, Kelly, Tom and Maree, were not able to identify any science skills they considered themselves competent in prior to the commencement of the programme. This could be attributed to the predominance of demonstration type science lessons they reported to have experienced in the past. The students may not have viewed the skills of prediction, observation and explanation commonly encouraged by teachers during demonstration lessons (Milne & Otieno, 2007) as science skills per se especially as they would have experienced these skills in other curriculum areas. By the end of phase 3, these students were able to identify more than one specific scientific skill in which they felt they had displayed considerable expertise (see Table 9).

Student	Procedural Doing Skills		Procedural Understandings	
	First focus group	Final focus group	First focus group	Final focus group
Kelly	-	• reading and following instructions • care with equipment • documenting data collection	-	• data collecting
Tom	-	• avoiding contamination of samples • maths skills for data analysis	-	• data collecting • data handling
Maree	-	• care with equipment • taking samples	-	• data collecting

Table 9: Kelly, Tom and Peter's perceptions of their scientific skills

By phase 3, Kelly considered herself to be competent in four science skills. These included reading and following instructions, taking care with equipment, and the documentation of data collection. She recalled working successfully with the water testing kit, in particular testing for nitrates and phosphates. When asked to elaborate she identified two specific science skills when using the water testing kit to test for nitrates, namely reading and following instructions. She was aware of each step in the process and was able to explain what she had to do in detail:

> you had to put some water into one [test tube], and then mix up pill one.Then after that had just about dissolved, you put it in a silver case and let it rest. After ten minutes we had to get it out, put the second pill in and mix it up (FG3).

Her description indicated an awareness of ensuring the collection of credible data by following instructions precisely, in particular with regards to the order the pills are dissolved, and the time period between the mixing of the first and the second pill.

She was also mindful of the importance of taking care when using equipment during a science experiment, "you had to make sure you were holding onto the lid of the container, otherwise when you were shaking it the lid would pop off and all the water will come out" (FG3). Implicit in her comment was the understanding of the importance of identifying a possible risk that could occur (water spilling out of the container) and what to do to control this risk (hold on to the lid of the container) to ensure the collection of reliable data.

Kelly was aware of the importance of keeping a record of what was actually happening during scientific investigations and considered photographic documentation as one of her strengths, "I'm good at taking photos … to actually make sure you get the person and the sample in it" (FG3). This suggests she understands the importance of recording accurate evidence of both the sample and the sample taker as proof of the data collection process to aid trustworthy data analysis.

By the end of the programme, Tom considered he was good at two science skills: avoiding the contamination of the samples; and using mathematical skills to analyse the data. To illustrate the skill of avoiding contamination of the samples, he described using litmus paper when testing water pH:

> You can't touch the end of it [litmus paper] otherwise the colour will turn. If you've got any contaminations on your hand and it goes on it, it might change the colour. So you've got to be careful when you're doing that (FG3).

Tom displayed an awareness of a possible risk factor (contamination of the testing end of the litmus paper) which could affect the accuracy of the testing and described how to control this risk (not touching the testing end).

In addition, Tom acknowledged his ability to use his mathematical skills to aid in the analysis of scientific test data. He considered he was proficient at calculations such as averages, "when we test three samples or three of the same samples and we've got to get the right average score" (FG3). In doing so, he displayed an awareness of a data handling process where it was necessary to arrive at a single value that represented all the sample readings in that group before the commencement of data analysis.

By phase 3, Maree also regarded herself as capable in two science skills. These skills involved aspects of taking care in science: care with equipment; and care when taking samples. First, she emphasised that she was good at being careful around equipment while carrying out a scientific procedure:

> You have to be like with your samples say they're sitting on your table or something, you have to be really careful that you don't knock them over when you've got those squeezy things, the droppers…And when you're getting them out of the little container… you have to be really careful you don't spill any (FG3).

She highlighted two potential risks (knocking over containers containing the samples of water, and spilling the test solution) which could compromise the reliability of the testing and indicated how to possibly control these obvious risks (by being careful). Second, she indicated her awareness of the process to ensure samples were free of contamination, "When we went to get our samples for our testing, I was real careful that that I rinsed the jar out like three times, so it didn't get contaminated" (FG3). She was alert to the fact that unclean equipment have the potential to distort the test results.

5.1.1.2 General to the precise

Although Peter, Jerry, and Ken were able to identify aspects of scientific skills they considered themselves to have some aptitude in at the beginning of the programme, these skills were somewhat general in nature with two of the students having difficulty elaborating on these skills or the scientific contexts within which these skills were used. Nevertheless, by the end of phase 3 these three students spoke confidently and knowledgeably about the specific skills in which they considered they had shown considerable ability (see Table 10).

Name	Procedural Doing Skills		Procedural Understandings	
	First focus group	**Final focus group**	**First focus group**	**Final focus group**
Peter		• measuring • maths skills • communicating	-	• data collecting • data handling • communicating data
Jerry		• avoiding contamination of samples • pH testing	-	• data collecting
Ken	• taking care	• measuring	-	• data collecting

Table 10: Peter, Jerry and Ken's perceptions of their scientific skills

Initially, Peter stated he was good at "solving problems" or "estimating" which he further defined as prediction, "guessing what would happen" (FG1). However, he was not able to give examples of when or how he had used these skills. He could be confusing these science skills with skills used in reading and mathematics, therefore this data was not entered on Table 8. By the programme's conclusion he was able to identify and describe in detail three specific areas he felt he had displayed considerable scientific skills: the accurate measuring of liquids; the use of mathematical skills for recording numerical data; and the sharing of research findings with an audience.

First, he emphasized the necessity to be very accurate in measuring liquids, giving a methodical explanation of how to measure to the meniscus of the liquid:

> I'm precise. Say you have a cylinder and you need 10mls of your sample in it, you pour it in and it has to be precisely on the thing [meniscus]… you have to look for the bottom of the dip, see if it's on the line (FG3).

Peter was aware of the importance of knowing how to use the equipment correctly to accurately measure so that data gathered was reliable.

Second, he made the link between science and mathematics. He acknowledged his skills in the mathematical area, "I reckon I think I'm good at the mathematical part" (FG3) and gave an example of recording numerical data from the collection of three water samples from each of the top, the middle, and the bottom of the water trough, "like when you get the average from the top, middle, and bottom samples…and then put them on the graph…I'm good" (FG3). Peter was aware there needed to be consistency in the test results, in other words, the need to identify the typical result of the three samples by calculating the average. Furthermore he was aware that graphing could be used to aid the interpretation of the test results.

Third, he identified communication skills as another strength, "I reckon I'm good at explaining what we did" (FG3). Then, he elaborated by detailing the scientific process his group undertook, starting with sample collection, testing the samples for pH, identifying the bugs found in the water and finally, explaining how the scientific investigation was communicated to the community audience, by "showing what we did on a powerpoint" (FG3). In doing so he demonstrated a developing understanding of the need to communicate the entire process of the scientific investigation, including the data interpretation methods used to achieve the results, in order to present believable evidence to an audience.

At the beginning of the programme, Jerry inferred he was good at predicting, “good at estimating what will happen - I think a lot about what will happen” (FG1) but he was not able to elaborate exactly what this meant with examples of either his thinking or estimating within the science context. Therefore, this skill was not entered on Table 8. Towards the end of phase 3, Jerry was able to identify two skills he considered he was good at in science: avoiding the contamination of samples, and pH testing.

He explained how he avoided contaminating the litmus paper when testing for pH, “Say I’ve got a paper strip … you can only touch the end. If you touch down there it contaminates the piece of paper so the reading doesn’t come out right” (FG3). This demonstrates he has an awareness that the causal effect of holding the litmus test papers in the wrong place has the potential to affect the accuracy of the pH reading.

Second, he admitted he was confident at pH testing water samples, “the pH testing, I’m really good at that” (FG3). He explained the process in a sequential order beginning with accurately measuring the water sample according to the meniscus, “first you’ve got to put the sample in so the bottom of the dip’s on the line,” then adding the exact amount of pH indicator solution, “you’ve got to do 8 drops of that,” and finally using the pH monitor to ascertain the pH of the sample, “then you’ve got this little thing with lots of different colours and it’s got a number below and that’s a pH number. And I’m really good at doing that and figuring out the number” (FG3). This explanation demonstrates Jerry’s understanding of how to pH test samples as well as the importance of keeping to this process in order to achieve credible results.

Prior to the beginning of the programme, Ken concentrated on safety issues that focused on taking care, especially with equipment, so it did not influence the outcome of the experiment. He considered he was, “careful not to knock anything over because if you knock over something it could go wrong” (FG1). He showed that he was aware of a possible risk that could occur during a scientific investigation (knocking things over) and a way of controlling this risk (being careful).

By phase 3, Ken still emphasized taking care, but this time with regards to the specific skill of accurately measuring liquids. He was able to explain in detail measuring to the dip of the meniscus on the surface of the water:

> Um there's a dip, but the real name for it is meniscus. And it's not the top of the water, it's where the bottom of the meniscus is. And when that bottom of the meniscus gets to the line that's when you stop (FG3).

Ken demonstrated an awareness of the necessity of being accurate in measurements in order to get consistent and reliable data.

5.1.1.3 Passive to active participation

The science skills Lisa, Shane and John initially identified involved what could be referred to as passive roles, such as watching or doing as the teacher requested in an assistant role. This could be as a result of the dominance of demonstration type science lessons the students had experienced in the past, whereby only the teacher and maybe some selected student volunteers were involved in the hands-on part of the science demonstration. By the end of the programme, all three students described science skills where they had a much more active role (see Table 11).

Prior to phase 1, Lisa considered she was "good at watching science movies like Suzie Sings" (FG1). She emphasized the watching aspect and did not indicate any involvement in, or recall of the discussion of ideas during or after the showing of the movie. In other words, she had a passive role, receiving, and accumulating knowledge. This "banking concept of education" (Freire, 1972, p. 42) tends to portray Lisa as a collector of knowledge rather than being an active, inquiring participant in the learning process.

Name	Procedural Doing Skills		Procedural Understandings	
	First focus group	**Final focus group**	**First focus group**	**Final focus group**
Lisa	-	• measuring • sample collecting	-	• data collecting
John	-	• measuring	-	• data collecting
Shane	-	• sample collecting	-	• data collecting

Table 11: Lisa, Shane and John's perceptions of their scientific skills

In contrast, by the end of phase 3, she considered herself good at skills that involved hands-on participation. She was aware of how to accurately measure liquids to the meniscus, "I'm good at measuring to the little dip" (FG3). Furthermore she acknowledged the importance of correct labelling of samples, "I'm good at labelling all my samples … [if] you get a sample from one place and you label it wrong, it all gets mixed up" (FG3). These skills indicate that Lisa was aware of the importance of accurate measurement and identification of samples to ensure trustworthy results.

Shane and John both indicated they were good in assisting roles, indicating a position of power inequality, whereby the teacher was in control and they were lending a hand. As a result they seemed to be first, not aware of the whole scientific process being demonstrated, second, not personally involved in the actual scientific process, and third, not necessarily reflecting on the science that they were observing. Therefore, their data was not entered on Table 8.

John indicated that he was good at "being an assistant" where he would "help and mix up the ingredients" (FG1). As he was not able to elaborate on either the context or the scientific process that was involved, it would seem that there was a strong possibility he was not making connections between what was actually happening and any science learning.

By phase 3, he was more focused on skills that he could personally do, thereby giving him more ownership of the task than if he was watching a demonstration type lesson. When measuring liquid into a cylinder using a pipette he advised that you, "don't just squirt it straight in and make bubbles because it would be hard to see if the bottom of the dip is on the line" (FG3). This demonstrates he knew the appropriate way to use equipment in order to carry out accurate measurements.

At the beginning of the programme, Shane took some time to think of what he was good at in science. He finally admitted, "I'm pretty good at holding the cups down in the water, I'm quite strong" (FG1). When asked to explain further, he indicated his role was to hold the cups down in the water for the teacher who was demonstrating the experiment to the class. He seemed to value his physical strength in this scenario as opposed to any scientific skills, content or understandings. As he was unable to demonstrate any knowledge or understanding of the scientific process being demonstrated it was likely that he was not making any links to the science concept under investigation.

By the end of phase 3, he considered he was good at sample collection and sample testing. He was involved in a group investigation which was investigating the pH and nitrates in the soil underneath cowpats and he was very particular about obtaining an accurate sample, explaining his procedure as "like not going over and just shovel up the whole thing. I was trying to get the spade underneath the cowpat [to get to the soil]" (FG3). This demonstrates Shane has an awareness of what to sample (the soil as opposed to the cowpat and soil) and also the process of how to do this (the spade underneath the cowpat) in order to produce an accurate soil sample that did not include parts of the cowpat.

Furthermore, Shane was able to give a detailed account of testing the soil samples in a centrifuge. This included putting water with the soil samples into "tiny little skinny test tubes", placing them in the centrifuge which made "all the dirt go down to the bottom" of the test tube, testing the sample with litmus paper and then using the water testing kit monitor to ascertain the pH. He was aware of following the correct process in order to gather reliable data.

The findings demonstrate all the participating students considered they had developed an increasing confidence in using scientific skills. The most improvement was noted in the area of data, namely data collection and handling. From a quantitative perspective, most students could identify an increased number of skills they considered themselves to be proficient in by the end of the programme. Two students increased the number of skills identified by one, four students increased the number of skills identified by two, and one student increased the number of skills by four. The two students who did not increase the number of identified skills over the duration of the programme did identify more specific science skills compared to the start of the programme, for instance John named assistant skills at the beginning compared to accurate measurement skills at the end. However, of more importance than the increase in the number of self-reported science skills capabilities is the students' understanding of what these skills are used for, why they are used, when they are used and how to use these skills. This aspect is examined next.

5.1.1.4 Thinking scientifically

All the skills mentioned by the students were procedural skills, otherwise viewed as "the mechanical aspects of doing science" (Feasey, 2012, p. 62). These skills are indicative of working scientifically. Further examination of the way the students talked about the scientific skills they considered they were proficient in revealed a growing awareness and understanding of the thinking behind working scientifically. This analysis is presented according to the ideas and decisions related to the collecting, handling, interpreting and communicating of scientific data (adapted from Feasey, 2012).

5.1.1.4.1 Collection of data

The majority of the scientific skills mentioned by the students involved the collection of data. Aspects within data collection included ideas and decisions related to the design of a test, measurements, risk identification and control.

Ideas and decisions related to the design of the test incorporate an understanding of what can be changed or altered or must stay the same when collecting data without changing the final outcome (Jadrich & Bruxvoort, 2011). Maree highlighted reading and following instructions, while Jerry and Tom identified pH testing samples with litmus paper as processes that must be kept the same throughout the scientific investigation in order to gather trustworthy data. The pH testing skills were taught by the Chemistry Outreach team when the group was involved in pH testing activities, therefore the Chemistry Outreach programme did influence the students' capabilities in data collection. Reading and following instructions was not explicitly taught but was encouraged in order to achieve accuracy in data collection. As a result, the students used these skills within an authentic, meaningful context and were aware their ability to be precise with these skills had the potential to influence the test results. This indicates a link between the Chemistry Outreach programme and the skills related to instructions.

Measurements represent quantitative observations involving, "a direct comparison between an object or event and a scale of reference" (Jadrich & Bruxvoort, 2011, p. 217). Four children spoke of the importance of measuring to the dip of the meniscus indicating their awareness of first, how to take measurements, second, what to measure, and third, why careful, precise measurements are important for accurate data collection. These measuring skills were explicitly taught by the Chemistry Outreach team within the context of science activities in preparation for the student-directed investigations. Therefore, the Chemistry Outreach programme did influence the students' development of measurement skills.

Risk identification and risk control relate to the important variables in a test situation that may influence the outcome (Martin et al., 2009). Several children identified various possible sources of contamination including unclean containers when taking water samples, and the contamination of testing papers by holding them in the incorrect place. Other children highlighted the importance of being careful around equipment to avoid spills, and labelling samples correctly. All children were aware of the steps to take to avoid or control these risks in order to produce credible scientific evidence. These skills were specifically taught by the Chemistry Outreach team to assist the students in the planning, designing, conducting and evaluating their own scientific investigations. As such, there is a direct link between the Outreach science programme and the growing awareness of the children with regards to risk identification and control.

5.1.1.4.2 Data handling

Mathematics skills are essential for scientific investigations as "science and mathematics are forever tied together by context and application. Science is the application of mathematical theory and understanding and mathematics is the language and primary tool of science" (Francis, 1996, p. 80). Mathematics underpins working and thinking scientifically (Feasey & Gallear, 2000). Tom and Peter specifically mentioned their mathematical skills in relation to science, referring to their ability to average multiple measurements taken several times in order to reduce the possibility of measurement inaccuracies through over or under estimation. Furthermore, Peter also identified graphing as a means to record data with the graph representing a visual aid which can assist in more effective data analysis (Feasey, 2015; Jadrich & Bruxvoort, 2011).

Both Tom and Peter are proficient mathematicians within the classroom mathematics programme, and this ability may have been the precursor to their confidence in using mathematical skills within a science context. The Chemistry Outreach programme provided a meaningful, authentic context to practise these skills, therefore the programme influenced their data handling skills.

5.1.1.4.3 Communication and data interpretation

Peter was the only student to mention skills relating to the communication of scientific data to an audience. Science is essentially a high social activity (Gopnik, 2012; Jadrich & Bruxvoort, 2011) where communication among, with, and to others is vital. Peter was aware that scientific evidence presented to an audience needed to include the entire process of how the scientific investigation was carried out, and how the results were arrived at in order for others to judge the credibility of the data. These skills were taught in conjunction with the students' self-directed investigations. As only one student mentioned this skill, the evidence is inconclusive as to the influence of the Chemistry Outreach programme on the participating students' communicating skills.

No students mentioned aspects of data interpretation skills. This could be due to the predominance of students' interest and active involvement in the hands-on data collection. However, this is not to say the students did not participate in making sense of the collected data but rather that this skill did not rate highly from the perspective of their lived experience.

All participating students demonstrated a developing confidence in using scientific skills, as well as an understanding of the why, how and what to do in scientific investigations. In doing so, they demonstrated a growing understanding of the ideas and decisions related to data collection and analysis, essential to producing trustworthy scientific evidence (Roberts, 2001). The majority of these skills were explicitly taught by the Chemistry Outreach team within a scientific context, in particular those relating to measurements and the identification and control of risks. Other skills, for instance averaging multiple measurements and graphing, were taught incidentally when required as part of the scientific investigation. All skills were taught and practised within authentic scientific contexts, as there can be a limited transfer of these types of skills if taught in isolation from a scientific context (Harlen, 2012; Jadrich & Bruxvoort, 2011).

As already indicated all these skills were procedural in nature, incorporating both the practical aspects of doing science and the procedural understanding of scientific evidence and scientific investigation. However, scientific inquiry also requires the ability to analyse and make sense of the data that has been collected. This aspect will be explored next within a social context.

5.1.2 Science skills within the social context

The data examining the students' use of scientific skills within the social context was collected from two videos. The first video was the jelly crystal activity (see Appendix D) prior to the commencement of the Chemistry Outreach Science programme, and the second video recorded the magnesium tape experiment (see Appendix E) during phase 3 of the programme. The analysis focuses on the roles the students undertook within the group in relation to the procedural doing skills and the meaning-making thinking skills. As mentioned earlier, it is not the accuracy of the meaning-making statements made by the students that is under investigation, but the process the students undertook to attempt to make sense from their perspective of what was happening during the experiment.

5.1.2.1 Group A Jelly Crystal Fair Test Activity: Lisa, Kelly, Shane

Lisa's role was predominantly as task controller particularly as far as Shane was concerned. She offered three ideas during the planning stage, one related to possible roles for the group members, and the other two were contributions towards the task plan. There were no contributions that indicated any attempt at making sense of the experiment. It was very noticeable that the remainder of her participation focused on the completion of the task as efficiently as possible. This brings into question whether Lisa was engaged cognitively with the task or if she was more involved with controlling Shane's actions to ensure this task completion. In other words, she was focused on the doing of the activity as opposed to thinking about the activity.

In contrast, Kelly concentrated on first, monitoring the task to ensure the focus was on the aim of the experiment and second, clarifying and making sense of ideas. Kelly was very aware the aim was to find out if jelly crystals dissolve faster in hot or cold water, unlike the other group members whose focus was diverted by the desire to include warm water. When the group had difficulty explaining how their plan was a fair test, she clarified their ideas, "it's a fair test because only one thing changed, the temperature of the water." After the task had been completed with the hot water, Kelly concluded jelly crystals dissolved better in hot water. Her conclusion was reinforced by her observation that there were still jelly crystals that had not dissolved in the cold water, "Yep, we've found out, it dissolves better in hot water, not in the cold because we still have some saturated stuff left." Her focus on the aim of the experiment helped her to engage in meaning-making as she attempted to make sense of her observations.

Shane attempted to take on the role of idea giver but appeared to have difficulty communicating his ideas in a logical, coherent manner so the group members could understand. When he was describing what happened to the jelly crystals in the hot water Shane was keen to answer but had problems articulating his ideas clearly and confidently. His ideas presented a mismatch with Kelly's and consequently she took it upon herself to 'correct' Shane by presenting her observations. It would seem that Shane was attempting to link his prior knowledge of hot air rising and cold air not rising to a context involving hot and cold water.

Shane: It went down to the bottom. Oh, it stayed up and the cold, the warm rising
Lisa: And then…
Shane: Shoosh, I'm trying to speak. The cold water goes up, I mean, the cold water stays down at the bottom and then the hot water rises.
Kelly: No Shane, what you're trying to say is that the hot water's the one that dissolves the flavour in quicker than the cold water.
Shane: That's what I was trying to say.

Although Shane verbally confirmed Kelly’s account was what he was intending to say, it is possible he may still hold to his original observations. These ideas, variously termed in research literature as ‘misconceptions’ or ‘alternative frameworks’ or ‘partial understandings,’ (Dawes, 2004) are based on the cumulation of Shane’s past experiences, present observations, and scientific knowledge to date. He may not yet be cognitively ready to accommodate or replace his ideas with more scientifically acceptable ideas. This is further evidenced by Shane often following ideas initiated by Kelly. To illustrate, when Kelly concluded the jelly crystals dissolved better in hot water, Shane agreed, reinforcing Kelly’s idea by saying , “yeah it feels better in the hot.” It would seem Shane’s choice of the word feels indicates he may be merely reiterating what he thought she said as opposed to personally thinking deeply about the ideas.

5.1.2.2. Group B: Jelly Crystal Fair Test Activity: Maree, Ken, Peter

Both Maree and Ken took on the role of task leaders, checking that the agreed procedures actually occurred, and controlling the pace of the activity in order to ensure the smooth running of the task to completion. They also dominated the contribution of ideas within the group setting and attempted to make sense of their ideas. Furthermore, they used their prior knowledge to help make connections between their observations and predictions. When Maree suggested they abandon their test with hot water because the jelly crystals seemed to be taking a long time to dissolve, Ken disagreed, “No, it will dissolve because that’s how you actually cook it” to which Maree concurred stating, “You make jelly with hot water.” Maree participated in making sense of her ideas when she attempted to explain her observation that hot water was the only one to dissolve the jelly crystals because, “the hot water heats it and it dissolves.” Ken, on the other hand, did not follow any of his observations with an attempt to explain.

In contrast, Peter initially took on the role as an initiator of ideas but his ideas were not acknowledged by the other team members. He subsequently limited himself to an assistant role whereby he helped with the execution of the task, but did not contribute any ideas of his own or react to the ideas of the group. His involvement was confined to checking with the group as to the way they wanted the task to proceed and following their instructions. Within the social context of this group, Peter participated in normalising behaviours whereby he regulated his involvement in order to achieve the desired norms of the group (Foucault, 1977). As a result, his participation in the investigation was limited to mainly procedural aspects of conducting the investigation as opposed to attempting to make sense of what he observed.

5.1.2.3 Group C: Jelly Crystal Fair Test Activity: Tom, Jerry, John

Tom's role was predominantly as task monitor ensuring the activity proceeded according to the groups' agreed procedure. He used his prior knowledge early on in the activity to predict the jelly crystals would dissolve quicker in the hot water. However, he did not combine this information with his observations to help him build ideas to make sense of what was happening. On the whole, he either reinforced or concurred with other group member's ideas. He was more focused on procedure than meaning-making as evidenced in the discussion session where he gave a generalised summary, "the jelly crystals turned out as we expected they would." There was no attempt to explain this statement further. He seemed to revert back to his original prior knowledge and not make any connections with the current activity to help grow his scientific understandings. Overall, Tom's focus was more on the procedural doing aspects of the task than thinking about what was happening.

Jerry helped monitoring the progress of the activity by checking instructions, ensuring the instructions were followed particularly in the initial stages of the activity, offering to assist other group members, and locating correct equipment. His initial ideas focussed on the colours of each solution. However, as the activity progressed he took on the role of idea initiator with suggestions as to how to modify the instructions when the crystals did not dissolve the way he expected, "mmm, it still didn't really make a difference, shall I put more cold in?" When they created a saturated solution, he challenged his accuracy in following the instructions and presumed they had used the wrong amount of jelly crystals. He attempted to make sense of what he was observing by making connections between whether the crystals sink or rise to the temperature of the water, “we found the cold ones sink and the hot water jelly crystals rise.”

John also participated in the monitoring of the progress of the activity. He was aware of the social context within which the learning was taking place and often involved others in the procedure, “We’ll do the cold water last ah Tom?” This was also evident in the collaborative meaning-making process when he sought agreement with his conclusions from other group members, “We’ll go with that one ah Tom? That dissolves way faster.” John was guided by the objective of the task and tried to make sense of his detailed observations during the activity. He was an initiator of ideas and attempted to make sense of them using prediction, “I’ll bet you all the stuff will go to the bottom,” and a tentative explanation, “I think the hot takes more colour than the cold water.” Throughout the experiment he was focused on the procedural aspects and in making sense of his observations.

5.1.1.4 Group A: Magnesium Tape Experiment: Lisa, Kelly, Shane

Lisa initially focused on monitoring the procedural aspects of the task including following instructions, turn taking, and assisting other group members, “I’ll tell you when to stop [measuring] Kelly to make it easier for you.” As the activity continued she became more involved in sharing her ideas. These initial observations identified physical aspects of the chemical reaction between the magnesium tape and the varying dilutions of hydrochloric acid, specifically the speed of the reaction, the smell, and the movement of the tape. However, as the experiment progressed her observations became more detailed. She compared the results with the previous tests, “we had heaps of smoke coming out [last time] and now we’ve got just a wee bit… and there’s not as much bubbles as there was before.” Then she attempted to explain, “that’s the longest one so far … maybe the water makes it go differently to the others, makes it go a bit slower.” Even at the end of the experiment she was still reflecting on what she had seen causing her to wonder how come it took so long. She was obviously still thinking this through because when it came to the discussion session she elaborated on her previous comments about water making it take longer, “because it is taking away the acid … and makes the magnesium dissolve slower.”

Kelly took on two types of roles within the group for this experiment. First, she was involved in the smooth running of the experiment. As task director and monitor she ensured everyone had a turn, clarified the responsibilities of each group member, checked members knew how to work the equipment (the stop watch), and regularly sought confirmation from the group that the measurements were accurate.

Second, she engaged in a variety of meaning-making strategies to help her make sense of her observations. These strategies included adding more detail to her observations, “dissolving… dissolving and making bubbles and smoke … it’s actually fog, sort of foggy smoke.” She also attempted to analyse why the times were not the same for each test, “times are closer so we could have done just a little bit of difference.” Furthermore, she attempted to explain why the different concentrations of hydrochloric acid reacted differently, “there’s still 50mls of liquid but they are not all the same kind of water, it’s sort of different water, it’s taking longer right now cause there’s less of the hydrochloric acid.” Interestingly, although Kelly was engaged in meaning-making throughout the experiment she did not contribute to the final discussion session. This could be explained by Lisa and Shane’s increasing dominance of the talk time from the middle of the experiment onwards.

Throughout the activity, Shane was involved in monitoring the progress of the task. This included assisting other group members with the accurate measurement of liquids, reminding others of the correct way of using equipment (pipette), checking what came next in the procedure, “do we do this three times?’and confirming with the group when it was his turn to record and measure. His observations focussed initially on the physical attributes of the steam and the smell but by a quarter of the way through the experiment, his comments advanced from general to more detailed as he attempted to understand what was going on. Taking on the role of builder of ideas, he compared the times with previous tests, reflecting, “I wonder what we did.” This led to connections with the amount of water in each test time and predictions for present test. He then tried to make sense of what was happening by explaining, “more water makes it go different.”

Comparisons with the first and second activites indicate a change over time in the roles the students undertook within the group. This occurred in both the procedural and the meaning-making aspects of the task (see Table 10).

	Jelly Crystal Activity		**Magnesium Tape Experiment**	
Student	**Procedural doing skills**	**Meaning-making thinking skills**	**Procedural doing skills**	**Meaning-making thinking skills**
Lisa	• task controller	-	• task monitor	• detailed observing • comparing • explaining • reflecting
Kelly	• task monitor	• clarifying and making sense of ideas	• task director/ monitor	• detailed observing • analysising • explaining
Shane	• assistant role	• following others' ideas • attempting to give ideas	• task monitor	• detailed observing • comparing • building ideas

Table 12: Comparison of Scientific Skills for Group A

In the first experiment, Lisa, as the task controller, was totally absorbed in the doing of the task thereby preventing her from engaging in any meaning-making thinking. In contrast, during the second experiment Lisa was a more co-operative team member working with others to ensure accuracy of task procedure, and she was also more engaged in sharing her observations and attempting to build ideas.

Shane progressed from delegated tasks to the more active involvement of monitoring the the procedure of the activity. Furthermore, he gained confidence in sharing, articulating, and attempting to build on his ideas about the phenomenon he was observing. Kelly dominated the meaning-making in the first experiment, and although she made considerable contributions to the second activity, it was noticeable that both Lisa and Shane contributed more ideas to the discussions. Overall, all the students in this group became more involved in attending to the procedural aspects of the task as a group, and were more engaged in various forms of meaning-making as they attempted to make sense of what they had observed.

5.1.1.5. Group B Magnesium Tape Experiment: Ken, Maree and John

Ken was active in monitoring the smooth progress of the experiment, ensuring the group kept to the instructions, reminding group members of their roles, assisting with the accurate measurement of liquid, and describing the correct use of equipment. He involved the group members in the procedure, “Right, who wants to do the hydrochloric acid?” as well as initiating discussion involving prediction, “How long do you think it’s going to take this time?” and meaning-making, “What do you think the water does to it?” His initial observations included physical aspects such as smoke and bubbles, as well as time predictions. When he attempted to explain what he saw happening he included cause and effect links, “I think it makes it longer, cause there is less hydrochloric acid and the more acid there is the less time it takes.”

Maree initially assumed the role of task director at the outset of the activity, delegating roles and responsibilities to the group members. However, as the activity proceeded, her role became that of a task monitor assisting other group members with their measurements, helping others to use the equipment correctly, and assisting with recording. Her comments involved both the observation of the physical aspects of the chemical reaction, and her emotive reaction to what she is seeing, “wow, that’s awesome, it’s moving around in circles, cool … oh yuk, it smells bad.” She attempted to predict what would happen, making connections between the time period and the concentration of the hydrchloric acid, “it’s going to be a shorter time because there’s less hydrochloric acid.” By the end of the session she had adjusted her thinking through making sense of what she had observed and explained, “it took longer cause it wasn’t as strong when you added the water and it took a lot longer.”

John took the role of task monitor assisting other group members with measuring, recording, using the equipment correctly and reminding them of the next steps in the procedure. His observations were detailed and focused mainly on the physical attributes of movement, smell, smoke and size. He predicted the water would affect the action of the acid and during the discussion session he expanded on this idea in his explanation "the water was wearing the acid. 40 mls acid plus 10mls water, it takes a bit longer."

Comparisons with the first and second activities reveal the modification of Ken and Maree's roles in relation to the procedural aspects of the task and the construction of meaning (see Table 13). In the first activity, they dominated both the procedural and the meaning-making aspects of the task. Maree did attempt early on to be consultative of all the group members when it came to the contribution of ideas but by this stage the other two group members were quite prepared to acquiesce to Maree and Ken's dominance.

	Jelly crystal activity		**Magnesium tape experiment**	
Student	**Procedural doing skills**	**Meaning-making thinking skills**	**Procedural doing skills**	**Meaning-making thinking skills**
Ken	• task leader	• idea giver • prior knowledge • connections	• task monitor • task involver	• collaborates with meaning-making • detailed observating • predicting • explaining • making connections
Maree	• task leader	• gives ideas • using prior • knowledge making • connections • explaining	• task director • task monitor	• detailed observing • making connections • predicting • explaining
John	• task monitor	• collaborates with meaning-making • initiates ideas • predicting • explaining	• task monitor	• detailed observing • predicting • explaining

Table 13: Comparison of Scientific Skills for Group B

In the second activity, Maree and Ken were more inclusive, involving others in the construction of meaning. Furthermore, they both reduced their control over the procedural aspects and took on a monitoring role, including others in the process in a collegial manner. The shift in roles for Ken and Maree could be attributed to the change in the group's social composition with John replacing Peter. John was regarded by Maree and Ken as their intellectual inferior within the classroom context, whereas Peter was regarded as intellectually superior. It could be conceivable that Maree and Ken stifled Peter's contribution to the meaning-making process in the first activity because they felt threatened by his intellectual skills. John, on the other hand, did not seem to pose an intellectual threat to them and therefore they were more accepting of his contributions. This is somewhat ironic because John, although not capable in most other curriculum areas, was in the opinion of the Chemistry Outreach team showing considerable signs of ability in the area of science.

Initially John was a member of Group C where he was proactive in working collaboratively with others in both the procedural and meaning-making roles. He continued with this approach during the second activity involving Ken and Maree in aspects of the procedure and the meaning-making process. His observations showed careful attention to detail throughout the investigation.

5.1.1.6 Group C Magnesium Tape Experiment: Tom, Jerry, Peter

Tom was involved in ensuring the experiment proceeded smoothly by agreeing to tasks delegated to him by others, consulting with others regarding the accuracy of his measurements, assisting group members with the correct way of using equipment, and checking on the group decisions regarding each member's role. He was also an initiator of ideas, giving detailed observations, often comparing one test with another, and followed by a prediction, "it's not smoking … well it is a bit, the smoke's coming out of just under the top and it's fading away and I reckon the tape's going to take longer to dissolve, like disappear." Furthermore, he displayed a sense of wondering when he experienced moments of cognitive dissonance, "it's only coming off the one edge … that's strange, and it's leaving all the bubbles behind it like before it didn't." Throughout the activity he attempted to make sense of what he was observing by using his understandings so far to make connections to help him explain what and why things were happening.

Jerry participated in monitoring the progress of the task by helping with the accurate measuring of the liquids, reminding group members of their turn, and offering to assist with the timing of the activity. His first comment indicated that he was not only identifying physical observable actions but he was willing to explore this phenomenon further, “it’s bubbly and it’s smoky, will it disappear or not?” Further comments involved comparisons, “it’s not putting on full steam like it did on test one” and predictions, “I don’t reckon it is going to last this time. I reckon it’s going to go at one minute and 20 seconds.” He displayed a sense of open-mindedness and willingness to question as he attempted to understand the phenomenon he was observing, “I wonder if the magnesium tape has a special thing on it to make the hydrochloric acid go all fizzy and funny.”

From the outset, Peter took a strong leadership role within the group, delegating roles in a consensus manner, giving guidance in accurate measurement, and reading the instructions throughout the duration of the experiment. He was very concerned with being precise especially with the measurement of the liquid, “yep, it’s exactly on the mark.” His initial comments focused on observable aspects such as the presence of smoke, the action of bubbling, and the smell but quickly developed into comparative observations and predictions. He dominated the development of ideas during the discussion session at the conclusion of the experiment demonstrating his ability to build ideas in order to make sense of what he had seen.

Comparisons with the first and second activities showed a continuation of Tom and Jerry’s procedural roles as task monitors. In contrast, Peter had a dramatic change from an assistant role where he was mainly checking with others how to do things, to task leader and monitor (see Table 14). Furthermore, during the first activity, Peter did not overtly demonstrate any involvement in the process of meaning-making which was in direct contrast to the second activity whereby he engaged in a variety of thinking skills in order to make sense of his observations. This somewhat remarkable transformation could be a result of Peter’s awareness of his intellectual superiority compared to Tom and Jerry within the classroom context, and this gave him the confidence to assume the leadership role and participate fully in the meaning-making process. However, it does cause one to wonder as to what exactly was Peter thinking but not verbalising out loud during the first activity.

	Jelly Crystal Activity		Magnesium Tape Experiment	
Student	**Procedural doing skills**	**Meaning-making thinking skills**	**Procedural doing skills**	**Meaning-making thinking skills**
Tom	• task monitor	• uses prior knowledge • predicting • reinforces others' ideas	• task monitor	• initiates ideas • observing • predicting • wonderings • connections • explaining
Jerry	• task monitor	• idea initiator • challenger • connections	• task monitor	• observing • questioning • comparisons • predicting • wonderings
Peter	• assistant role	-	• task leader and monitor	• observing • comparisons • predicting • gives ideas • makes sense

Table 14: Comparison of Scientific Skills for Group C

In the first activity, although Tom was aware of prior knowledge relevant to the phenomenon under investigation, he did not use this information to help him to further develop his thinking. Furthermore, he did not come up with original contributions but followed others' thinking. However, in the second activity, Tom was more proactive in meaning-making process, and showed confidence in using a wide range of skills such as detailed observations, predictions, wonderings, connections, and explanations to help develop his scientific understandings.

Jerry, on the other hand, was very involved in meaning-making from the first activity, questioning and challenging his observations, and suggesting modifications to the test design when met with unexpected results. These skills were developed further during the second activity where his observations became more detailed, and he used a range of skills including comparisons, questioning, and wonderings to add depth to his observations and assist in his attempts to make sense of the phenomenon under investigation.

5.1.1.7 Underlying influences

The findings of this study have highlighted several influences on students' use of scientific skills. These included: the dominance of procedural talk in peer-led group discussions; the categories of the skill of observation; and the small group as a micro-learning community.

There is a dominance of procedural talk as opposed to the fostering of meaning-making in peer-led small group discussions (Jiménez-Aleixandre, Rodriguez & Duschl, 2000; Young & Talaquer, 2013). To a certain extent, this is what happened within these small group science activities. However, the design of the second activity which involved nine tests compared to a minimum of two tests in the first experiment may have been a contributing factor to the increased procedural talk. Although statistically there were more procedural than meaning-making talk when comparing the first activity with the second one, it is the developing complexity of the students' observations over time that is of particular interest to this study.

The skill of observing can be regarded as the foundation of scientific meaning-making, as observing is the first stage in information collection and is used through the inquiry process (Charlesworth & Lind, 2003; Lind, 2005). Observations can be categorised in a hierachical way from 'looking at' (or gazing), 'observing', and 'seeing as' (Roth, 2005a). Similar to what we do everyday when travelling to work or school, when students 'look at' something they do not deliberately structure what they see according to patterns or categories. 'Observing' however involves more conscious thought where students structure the world according to specific characteristics by using new language and concepts to link their prior experiences with their present experience. The more complex 'seeing as' involves constructing an observed event or phenomenon according to the models or theories within the culturally shared world of science, for instance "seeing an ice skater as an instance of conservation of angular momentum" (Roth, 2005a, p. 257). As all the participating students' observations became increasingly more detailed over time resulting in more attempts at meaning-making through comparisons, predictions, connections, and explanations, it would therefore appear that these students were transitioning from the initial stage of 'looking at' (gazing) to the more involved 'observing' category. There were no instances of the complex skill of 'seeing as.' This could be attributed to the students' age and lack of exposure to scientific models or theories.

The examination of students' use of scientific skills within a small group context, revealed socio-organisational aspects which had the potential to impact on individual student's learning (Southerland et al., 2005; Varelas et al., 2007). These included: the selection of group members; role negotiation; group working relationships; and group acceptance or otherwise of individuals' contributions.

The selection of group members within small groups can have an impact on student participation and learning. Small groups can be considered as micro-learning communities influencing the student learning process (Varelas et al., 2007), and as such are predisposed to the "nuances of the context and the ways in which nuances shape the process" (Southerland et al., 2005, p. 1034). It is pertinent at this stage to indicate that the initial group selection was undertaken by myself as teacher, taking into account individual student's abilities and classroom social relationships. Therefore, I considered these groups to be effective learning groups. However, the composition of the groups for the second activity changed at John's request and this resulted in John and Peter changing their groups. John did not offer a reason for not wishing to continue working with the original group, but as it is not unexpected for very small rural schools to have all family members in the same class, the fact that all his siblings were in the original group could have been a contributing factor.

Role negotiation with small groups can also have an effect on student learning. Group work is indicative of real-world problem solving undertaken by scientists who invariably work in collaborative groups (Jadrich & Bruvoort, 2011). Roles undertaken within these group contexts involve "interpersonal relationships, group processes, and intergroup behaviour" (Brewer & Hewstone, 2004, p. xi). The roles for the students' activities were not prescribed for the students but either self-selected or negotiated within the group. Examination of individuals' roles over time showed an increase in more cooperative teamwork skills where students supported each other as they monitored the progress of the task together as opposed to one individual in the group dominating the process. Lisa is a prime example of this as demonstrated by her dominance of Shane's actions in the first activity, and the support, encouragement and appreciation of Shane's efforts in the second activity.

Group working relationships are influenced by the preservation of social harmony within a group which can occur "at the expense of thinking and behaviour that might lead to deep learning" (Anderson, Thomas & Nashon, 2008, p. 531). Initially Peter was excluded from effective participation in the meaning-making process by the other group members and this lead to Peter's self-regulatory behaviour focusing on the doing as opposed to the thinking about the activity. As such, he was drawn into the self-fulfilling prophecy of group relationships (Cohen, 1997) by automatically taking on the role as delegated by the group. However, in the second activity he saw his role as leader and immediately assumed this role, taking an active part in the meaning-making process.

The group's acceptance or otherwise of an individual's contributions can be influenced by the perceived academic status of individual group members. Therefore, students perceived as having high academic status can dominate discussions and their ideas are accepted by others whereas students with less academic ability were often marginalised and their ideas had little chance of influencing the meaning-making process (Bianchini, 1997; Moje, Callazo, Carrillo & Marx, 2001). However, the results of this study show that the influence of academic status within the group context is more complex than is represented by these researchers. Peter who has high academic status was marginalised in the first activity when he was working with students of a lower academic status. Yet he dominated in the second activity when he was in a group with lower academic status students. This could possibly be as a result of Peter feeling more confident and assertive with the second group members indicating that social relationships within the group setting can affect the meaning-making process. On the other hand, John, a popular boy with low academic status, dominated the meaning-making discussions in both group sessions. It would appear that the social and academic status of members within a group learning context can affect individuals' cognition and behaviour.

5.1.3 Discussion of Scientific Skills Results

This study highlights the Chemistry Outreach programme's positive influence on all the participating students' use of procedural doing and understanding skills. The students reported more confidence in using procedural skills improved over time and they demonstrated a growing awareness and understanding of the thinking behind the working scientifically, particularly in the area of data collection and data handling. This resulted in the students developing an understanding of how, when and why these skills are used. These skills were specifically taught by the Chemistry Outreach team within the context of science activities in preparation for the student-directed investigations.

All the participating students demonstrated an increased ability and confidence in using procedural and meaning-making scientific skills within small group scientific investigations. This can be attributed to the format of the Chemistry Outreach programme, which incorporated the development of scientific skills with the construction of scientific knowledge. Students participated in a range of scientific practices within authentic contexts culminating in the planning, designing, conducting, and evaluating their own scientific investigations. Furthermore, involvement in the processes of scientific investigation helps students develop conceptual understandings (Skamp, 2007). As inquiry involves the interrelated processes used by the scientific and student communities when developing scientific investigations (Simsek & Kabapinar, 2010), the Chemistry Outreach programme can be considered as an inquiry-based programme where the students were actively involved in hands-on investigations and activities.

Many researchers advocate the teaching of scientific skills within scientific inquiry, with connections to real-world contexts with multiple opportunities to experience and practise the skills (Monhardt & Monhardt, 2006; Skamp 2007; Turpin & Cage 2004). The findings of this study are consistent with the results of similar recent studies that found scientific skills improved as a result of: an inquiry-based programme (Simsek & Kabapinar, 2010); an inquiry approach to teaching compared to traditional methods (Anderson, 2002; Yager & Akcay, 2010); a hands-on inquiry-based approach (Ergül et al., 2011; Turpin & Cage, 2004); and a hands-on cooperative learning approach (Bilgin, 2006). It is of note that Dökme and Aydinli (2009) advocated more hands-on investigations as a way to improve students' abilities in the scientific skills. Hands-on investigations were an integral part of the Chemistry Outreach programme, and the students had plenty of opportunities to use, practise, and develop their ability in the scientific skills within small groups of 2 to 4 members. The importance of the opportunity to practise scientific skills echoes research by Wu and Hsieh (2006) who found students only made a moderate improvement in skills when they had limited opportunity to practise, compared to a significant improvement when there was more time to practise skills.

The Chemistry Outreach programme progressed from a structured inquiry to an open inquiry format, with the findings indicating an improvement over time in the students' use of scientific skills. This research adds to the limited research on scientific skills that specifically details the degree of inquiry, as well as the teacher role, student role and type of student work (for details see 3.3). However, the results of this study need to be read with caution in relation to comparing the impact of a structured or guided inquiry with an open inquiry approach. There was no control group in this research design and the students had many opportunties to practise their skills throughout the programme, therefore making it difficult to establish whether the inquiry type or the programme design had the most impact on the use of scientific skills.

Group work was a feature of the Chemistry Outreach programme. Socio-organisational aspects had the potential to impact on individual student's learning (Southerland et al., 2005; Varelas et al., 2007). The findings back up various assertions in literature that there are interconnections between cognitive behaviours and social relationships which can have the power to include or exclude individuals' participation in the use of scientific skills within a group context (Anderson et al., 2008; Southerland et al., 2005). However, the findings run counter to the widely expressed view students with high academic ability dominate group discussions and their ideas are more readily accepted by group members (Bianchini, 1997; Moje et al., 2004). The results in relation to Peter indicate the influence of academic status within the group context is more complex than indicated by these researchers.

Over time, there was an increase in more co-operative role negotiation, group working relationships and group acceptance of individual's contributions. This can be attributed to the format of the Chemistry Outreach programme where all science activities were undertaken in small group contexts and teamwork skills were modeled and encouraged by the Chemistry Outreach team, in contrast to the students' prior experiences of demonstration type science sessions.

5.2 Scientific Language

This section reports on the influence of the science initiative programme on the students' use of scientific language. As already noted, the examination of the students' use of scientific skills and scientific language can give an indication of the students' cognitive connectedness with school science. However, this does not mean that this study will take a summative perspective where competency with the correct scientific vocabulary by the end of the Chemistry Outreach programme is under investigation. Rather, the focus of this study is concerned with the process the students experienced as they developed their ability to use language to convey the way they see the world around them.

In the context of this study, scientific language refers to either one or more spoken words used to represent scientific ideas or concepts. As discussed in the Literature Review (see 2.4.1), scientific language is a specialized language, incorporating specific vocabulary to label objects (e.g. vertebra, test tubes), name processes (e.g. combustion, evolution), and identify theoretical concepts (e.g. electrons, molecules). Scientific language also uses sensory conceptual words related to colour, shape or feel (e.g. red, cold), everyday words that have a different meaning within the scientific context (e.g. power, energy), as well as relevant mathematical words and symbols such as neutral, $E=mc^2$ (Gee, 2005; Lemke, 1990; Wellington & Osborne, 2001). Furthermore, there are specific discursive patterns exclusive to scientific language, which help with the clear, logical communication of science ideas (Jones, 2000; Wellington & Osborne, 2001). These include logical connectives, qualifiers, nominalization, and creative literacy devices. Logical connectives to link ideas by contrasting (e.g. conversely), identifying cause and effect (e.g. because, so), establishing conclusions (e.g. therefore), indicating time sequences (e.g. after that), or making inferences (e.g. on the basis of). Qualifiers indicate the language used when indicating a tentaive as opposed to definitive conclusion (e.g. some). Nominalization is where nouns replace verbs or adjectives (e.g. absorb becomes absorption, flexible becomes flexibility), and creative literacy devices include metaphoric abstraction (e.g. the flow of electricity is referred to as a current). Specific grammatical features are used in scientific language especially when reporting or recounting scientific ideas or investigations, and include the use of the timeless present tense, and general pronouns (we, you) as opposed to first personal singular pronouns (I).

In this study the focus of this study is on the students' use of scientific language on the individual level, and within the social context of small group science activities. The individual level investigates students' use of scientific language in their recounts of school science experiences, while the social level examines the use of scientific language within small group science activities.

5.2.1 Recounts using scientific language

The data used to explore the students' use of scientific language was obtained from the initial and final focus group interviews. During these interviews students were asked to describe what they had done in school science. Students' responses were analyzed according to the information transmission role of language in science, that is, the labelling and communicating of established scientific knowledge (Sutton, 1998). The focus was on first, the use of specific scientific language and second, the use of scientific discursive features.

All students, with the exception of one, demonstrated an increasing use of scientific language to describe their science experiences over the time period of the Chemistry Outreach programme. The analysis of the data identified three sub-themes that described the students' change towards this increasing use of scientific language. These sub-themes included: transitioning towards using scientific language; labelling to describing/explaining using scientific language; and describing/explaining in everyday language progressing towards scientific language.

5.2.1.1 Transitioning towards using scientific language.

At the beginning of the programme, Jerry and Lisa were not able to name or recall any details of previous school science experiences. This could be attributed to these students not recognising science activities within an integrated curriculum programme, a common occurrence for New Zealand primary school students (Bolstad & Hipkins, 2008; Fraser, 2000; Gluckman, 2011). From an analysis perspective, this meant there was no initial data to work with, as opposed to presuming these students were not able to use scientific language. The data used for this analysis therefore comes from the third focus group interview in phase 3. By this stage of the programme, Jerry and Lisa were able to recall and describe science experiences, and offered explanations for their observations using varying degrees of scientific and everyday language.

Jerry described the main sequence of events in a helium balloon experiment, using mainly everyday language. He used the correct scientific terminology to label the gas, "When they came down with the helium, we put it in the balloons, and we put it to our mouth and we let it go out and then we were speaking, like … real funny, like squeaky" (FG3). In his attempt to offer an explanation to explain why it happened, he demonstrated he was aware it had to do with the vocal cords but was not able to confidently state the exact cause and effect, “because the helium, um it, doesn’t it get in down, in your throat and it tickles your throat?” (FG3). His use of ‘doesn’t it’ indicates he was feeling unsure, and he was seeking confirmation from the interviewer or focus group members that his way of looking at and talking about the experience was the same as their way. Jerry used a variety of scientific discursive features, for example, timeless present tense, general pronouns (we, you), the use of sequential connectives (when ... we) and causal connectives (because).

Lisa’s recall of a science experiment involved magnesium tape in a weak solution of hydrochloric acid:

> We put some sort of water into a cylinder … it was hot water … it was some sort of water, I can’t remember the name … um, acid. And we put magnesium tape in it and the magnesium tape sort of floated around in circles and bubbled until it disappeared … it dissolved … it sort of dissolved into the acid (FG3).

She used scientific vocabulary to label objects, for instance cylinder and magnesium tape. Lisa also used a rhetorical bridging device (Lindfors, 1999) to make the connection between everyday language and scientific language. She did this by first using everyday language and then attempting to use the correct scientific language, “it was some sort of water … it was hot water ... acid” (FG3). This emerging use of scientific language was further evident when she described the action of the acid on the magnesium. At first she indicated that the magnesium, “bubbled until it disappeared” and then she used the more specific scientific process terminology, “dissolved.” This indicated that this specific scientific terminology was still in the evolving stage for Lisa and therefore was not firmly established within her scientific language repertoire. Her use of a bridging device allowed her to remain in the discursive world where she was confident, that is in her everyday language, and then tentatively reach out towards the scientific language. Students often use this bridging device as a link, “between the ways they know the world and the ways others know the world” (Moje et al., 2004, p. 44). Scientific discursive features used included third person pronoun (we) and the linkage of sequential connectives (and).

5.2.1.2 Labelling to describing and explaining

In response to the question about what they had done in science, Kelly and Peter named the phenomenon they had studied with no details or description of what they had done or what knowledge or understanding they had gained. By the end of the programme, they were both able to first, describe an experiment and second, attempt to offer an explanation for their observations. Kelly used some scientific words whereas Peter used everyday language.

Prior to the programme beginning, Kelly listed a number of science topics when asked to recall school science experiences, "water dam, sun, moon" (FG1). By the end of phase 3, she was able to describe an experiment that occurred during phase 1, confidently using scientific labelling vocabulary such as liquid nitrogen and solid:

> The scientist brought along some liquid nitrogen and some onions and they put them in the nitrogen, and the onions all turned solid, and then we had to use a glove and throw them against the concrete and they smashed like dishes (FG3).

Kelly suggested a simple cause and effect link using a causal connective structure (because) to explain her observations, "because the liquid nitrogen was really cold so it like turned the liquid inside the onion into a solid like ice" (FG 3). She was able to further explain the concept of solid, "solid like ice" (FG3). This explanation came in the form of double talk, a scientific discursive feature using both scientific and everyday language (Brown & Spang, 2008). Double talk is where the speaker presents two versions of the same idea in order to aid the clarity of meaning for the listener. In this example, Kelly followed the double talk pattern by stating the scientific terminology, "solid" which is immediately followed by an explanation in everyday language, "like ice." In this instance, double talk is not a definition of the science concept as such, but rather the use of a combination of everyday and scientific language to provide clarity. Kelly also used a variety of other scientific discursive features such as timeless present tense, general pronouns (they, we), sequential connectives (and then), and causal connectives (because).

At the beginning of the programme, Peter named the science activity but did not connect it to any science learning, "paper duck flying competition" (FG1). By phase 3, he was able to give a simple description of a science experiment, **"**when us year 6's went to Dunedin, we made boats out of tinfoil and then we put soap on some Blu Tac and put it at the back" (FG3). Peter attempted to give a simple explanation as to why the boat moved through the water, "and the soap was pushing the water away, to make it run by itself without pushing it" (FG3). His use of everyday language in both his description and explanation will be examined more closely later in this section. There was evidence of the use of some science discursive features for example, timeless present tense, general pronoun (we), and sequential connectives (and then).

5.2.1.3 Describing/explaining in everyday language progressing towards scientific language.

Initially, Ken, Maree, John, Tom, and Shane gave an account of a school science experience using everyday language. Ken was the only student not to offer an explanation of his observations. By the end of the programme, all these students gave descriptions and explanations using varying degrees of scientific language, demonstrating their developing ability with using more technical scientific terminology.

Initially, Ken was able to give a simple description of an experiment in everyday language, "The teacher got some lemonade and some blackcurrants and put the blackcurrants into a plastic cup and they started started going up and down (FG1)." He was aware that he was not able to offer an explanation, "I don't really know why though" (FG1).

By phase 3, Ken was able to describe an experiment and demonstrate his developing ability to use correct scientific labelling terminology and symbols:

> We got some samples from home, from like ponds and troughs and rivers … We got some ice cartons, put river water into it or another kind of water and put the red cabbage indicator into it…and it turned like a colour, and we looked on the scale to see what kind of pH it was, and most of it was around about like purple … above neutral (FG3).

Furthermore, he was able to describe the scientific learning he had gained over the programme to assist in his explanation:

> We learnt the pH scale… basic, neutral and acid, and acid was one, neutral was seven, and basic was around about fourteen. It went from one to fourteen… if it's really lower, it's acidic, that's very dangerous and if it's very high, it's basic and that's dangerous too (FG3).

Ken's use of scientific vocabulary included labelling words (indicator, acid, acidic), everyday words that have a different meaning in the scientific context (basic) and mathematical language and symbols (scale, neutral, pH). His use of these scientific words within the context of recounting a science experience demonstrated his ability to use and understand this specific scientific vocabulary. There was also evidence of some scientific discursive features such as general pronouns (we).

Prior to the programme, Maree was able to give an account of a science experiment illustrating the action of yeast. She used everyday language to explain the sequence of events:

> I'm pretty sure it was baking soda or something and water in a cup and we put some yeast on top and mixed it altogether. And then we left it in the cup and then about an hour and a half [later] it all started to bubble up and it overflowed the cup (FG1).

She used a causal connective to explain her observations, "because the baking soda and the yeast were mixing together" (FG1). By the end of the programme, Maree was able to describe with confidence the three states of matter using scientific terminology and illustrating with examples:

> the three states of matter … solid, liquid and gas … the particles in a solid are all like scrunched … well, they're all together and they don't break apart - like a table … and in gas they move around a wee bit, but not that much, like no … they move around everywhere and they can be free, and liquid is like water and they can move a wee bit round … and liquid is like water, gas is all the air (FG3).

In this example, she used scientific labelling words (solid, liquid, gas) and words to indicate scientific theoretical concepts (three states of matter, particles). Her use of the word 'scrunched' indicates the use of a reaching device (Lindfors, 1999) where students use creative literacy devices to further extend what they know in an attempt to make sense of the scientific phenomenon they are experiencing. She also described making green eggs and gave an explanation with some scientific vocabulary including the use of scientific labelling words (indicator), as well as mathematical language used within the scientific context (neutral), "We got the yolk out of the egg and there was the white left, and we put the red cabbage indicator with that, and it went green … because… it was neutral" (FG3). Scientific discursive features included the use of generic nouns (solid, liquid, gas), general pronouns (we, they) and causal conectives (because).

Prior to phase 1, Tom was able to describe a school science experience using everyday language with some attempt at explanation:

> The teacher had this big bottle and it had bluey baking stuff in it and then we put a cup in it with a paper towel in the cup but no water was going in and we found that air takes up space (FG1).

By the end of phase 3, Tom attempted to use specialised scientific symbols for concepts such as water (H_2O) when explaining why his group's tinfoil boat moved through the water with Blu Tac on it. He used scientific words for theoretical concepts (molecules) as well as symbols (pH, H_2O). It is of note that he corrected himself when he realised he had confused the chemical symbol for water with that indicating pH, "cause it breaks the pH **…** oh no the H_2O." This self-correction indicates a growing confidence with the use and understanding of this scientific terminology. He then went on to explain further "cause there's molecules, they're called H_2O, like there's heaps of them that are joining up, to make water… and they just break them and then it forced the boat to go forward" (FG3). This further illustrates his growing awareness and use of specific scientific terminology, as he transitions from vague macroscopic descriptions like "bluey baking stuff" to the more precise microscopic "molecules called H_2O". Tom's use of scientific discursive features included third person pronouns (they, it), timeless present, causal connectives ('cause), and generic nouns (molecules).

John's initial description of a school science experiment was similar to the one described by Tom. Likewise, John used everyday language highlighting the main events of the experiment:

> The teacher got a bottle and she put some water in it and some food colouring then she grabbed a cup and glued a paper towel to the bottom of the inside of the cup and put it in the jar and the paper towel didn't get wet (FG1).

In addition, he made an attempt at a simple explanation for his observations by using a causal connective, "because air takes up more room" (FG1).

By the end of the programme, he was able to recall a science experience from phase 1, "When you put the onions in it, because the liquid nitrogen is like minus something degrees … when you put the onion in it, it freezes the onion" (FG3). He was able to apply his scientific knowledge in his explanation to make a cause and effect link for his observations, "because the liquid nitrogen is like minus something degrees, it freezes the onion" (FG3). His scientific language included labelling words (liquid nitrogen), process words (freezes) and mathematical language (minus, degrees). Scientific discursive features include the use of causal connectives (because), general pronouns (you, she).

Shane was able to to recall the sequence of the main events of a science experiment, "put some Blu Tac then a tissue and there's a jug of water and if you push the cup in and hold it for a few seconds … it feels funny" (FG1). He then gave an explanation for his observations, "then once you bring it up, the tissue isn't wet cause like the air is holding the water from getting it and hitting the tissue" (FG1). He used everyday language in his explanation using a causal connective 'because' and a sequential connective 'and then'.

By the end of the programme, he was able to describe in detail the procedure for testing soil samples by placing them in water and spinning the resultant solution in a centrifuge:

> We had to put the samples into a tiny little skinny test tube and we had to put them into a thing that spins around [centrifuge] and it makes all the dirt go to the bottom. And if you shake them, all the dirt would go down to the top again. And you'd have to do it again, and it took about about a minute to do that. Only six of them could fit in it [the centrifuge]. Then you took them back and then you put the piece of [litmus] paper into the test tube and brought it out and then you put it up against the window with a monitor thing that tells you what what it is … if it's acid or base (FG3).

Shane used predominantly everyday language in his description. However, there was evidence of the use of scientific language with labelling words (test tube, monitor, acid) and everyday language that has a different meaning in the scientific context (base). Scientific discursive features included general pronouns (we, you), generic nouns (samples), and sequential connectives (then).

The findings revealed that by the end of the programme eight of the nine students demonstrated an increase in the use of scientific language (see Table 13). At the beginning of the programme, two students did not identify a science experience, two students labelled the phenomenon under investigation, one student described a science experience, and four students described and explained their science experience. Everyday language was used for all the descriptions and explanations.

Name	Labelling	Process	Sensory concepts	Everyday (different meaning)	Theoretical concepts	Mathematical language and symbols
Jerry	helium					
Lisa	cylinder acid magnesium tape	dissolved				
Kelly	liquid nitrogen					
Peter	-	-	-	-	-	-
Ken	indicator acid acidic			basic		scale pH neutral
Maree	indicator				3 states of matter particles	
Tom					molecules	pH H_2O
John	liquid nitrogen	freezes				minus degrees
Shane	test tube acid			base		

Table 15: Use of Scientific Vocabulary in Phase 3

By the end of the programme, all students except Peter demonstrated the use of scientific vocabulary in their description and explanation of a science experience. The scientific vocabulary the students used was categorised according to Wellington and Osborne's (2001) taxonomy of the words of science (see Table 13). Overall, the students used eight different labelling words, six words using mathematical language and symbols, three words which denoted theoretical concepts, two everyday words with a different meaning in the scientific context, and two process words. The limited number of total science words used could be attributed to several students selecting the same experience to talk about.

The results for the scientific discursive features would seem to be inconclusive. Even though the results indicate an increasing use of the scientific discursive features, some limitations arose during the analysis process. The language features criteria for written recounts as outlined in the e-asTTle writing resource[13] used by many New Zealand primary school teachers, include action verbs (climbed, played, swam), past tense, connectives showing time sequence (first, then, next), nouns related to the event - specific people, places and happenings, descriptive and emotive terms, and the use of first person pronouns (I, we). Scientific discursive features are similar in respect to sequential time connectives, and nouns related to the event. Differences include the use of specialised scientific terminology, the use of general pronouns (we, you), the use of timeless present tense, as well as the lack of descriptive and emotive terms. As all the students were involved in writing recounts as part of their literacy programme during the period of the Chemistry Outreach programme, this could have had the potential to influence their choice of language and grammatical features in their verbal recounts of science experiences. Therefore, these findings need to be read with caution due to the similarity of some of the science language discursive features and the discursive writing features expected of students when recording a recount.

The rest of the analysis focuses on scientific language results. The findings regarding the students' use of scientific vocabulary need to be read in relation to the context. The focus group interview method as a data gathering method to research student talk can be influenced by a variety of factors including the positioning of the students in relation to the interviewer, the interviewer's language, and the social context, thereby possibly affecting students' responses (Roth, 2005c; Schoultz, Säljö & Wyndhamm, 2001). I was aware that during the focus group interview situation I had a multiplicity of positions in

[13] The language features for recounts were sourced from the Structure and Language Teacher Notes from e-asttle.tki.org.nz/Teacher-resources/Marking-resources-for-e-asTTle-writing.

relation to the students, as research interviewer and as their classroom teacher and school principal. As the science classroom dialogue involving sessions with the Chemistry Outreach team and classroom teacher consistently included everyday and scientific language, students could perceive that the expectation was that if the teacher was present, science discussions should include scientific language. As a result, the students would attempt to use more scientific language in contexts where the teacher was present. In other words, the students' focus was on 'the what' and 'the how' when they recounted a science experience. 'The what' entailed the describing and explaining of a science experience and 'the how' involved consideration of the language used to describe the experience to meet their preconceived conceptions of the teacher/interviewer expectations. Furthermore, the third focus group recounts consisted of Chemistry Outreach experiences that had been discussed as a class within the last 12 months using both scientific and everyday language. Therefore, students might be able to recall the scientific language used in the discussions. The open questioning format of the focus group interview enabled students the opportunity to be selective in their choice of experience, with some students perhaps selecting experiences they may consider they could explain with some scientific language.

Of particular note was Peter's use of everyday language at the end of the programme. As already indicated, Peter was regarded as a very capable science student by his peers and myself as his classroom teacher. He always contributes to class discussions, making thoughtful, relevant comments. Peter had been exposed to the same scientific language as the other students during the Chemistry Outreach programme and yet, at the end of the programme, he was the only student to use only everyday language in his recount of a science experience. Was his use of everyday language an indication of an inferior form of thinking? Does his use of everyday language constitute a hindrance to his scientific learning? Moreover, does the use of everyday language indicate that he was not cognitively engaged with the subject matter? The answer to these questions requires closer examination of the concepts Peter was attempting to explain. Peter chose to recount a science experience involving tinfoil boats with soap on the back moving through the water. This experience is a complex scientific phenomenon to explain as it involves the concepts of water surface tension and the effect of the soap on the water molecules. His observations, including his attempt at explaining how it happened, “and the soap was pushing the water away, to make it run by itself without pushing it” alludes to the soap weakening the surface tension of the water therefore not allowing the water molecules to bond. Peter had been introduced to the appropriate scientific language during classroom discussions of the experiment, but he still needed the opportunity to use “emergent language forms” (Varelas, Pappas, Barry & O’Neill, 2001, p. 28), while his scientific understandings were developing. In other words, he used his own way with words to articulate his observations, in order to own this way of talking and thinking about the world. Therefore, the use of everyday language is not inferior to the scientific language evident in textbooks. Rather, it is part of the process students go through as they develop their ability to understand and express scientific ideas.

It follows then that the use of scientific language is not the only way to describe a science phenomenon (Brown & Ryoo, 2008; Roth, 2005b). Students’ uptake of scientific language is more complex than code switching from one language to another as one does when learning a second language (Roth, 2005c). It is inextricably linked with meaning and the understanding of scientific concepts and ideas. The next section examines closely the student talk with group settings based on the premise that science is a social activity and science classroom talk is a social mode of thinking that attempts to make sense of the world (Mercer, 2004, 2008), therefore scientific knowledge is talked into being (Gallas, 1995; Lemke, 1990; Siry et al., 2012).

5.2.2 Scientific language within the social context

The data used to investigate the students’ use of scientific language within the social context was gathered from the two videos of the students engaged in science activities. The first video was the jelly crystal activity prior to the commencement of the programme and the second video was the magnesium tape experiment during phase 3. Students’ responses were analyzed according to the interpretative role of language in science, that is, tentative speculations in meaning-making during the process of developing new understandings (Sutton, 1998). The analysis focuses on first, the process one student, Shane, went through in order to use and understand the scientific vocabulary related to dissolution, and second, the process a group of students experienced as they engaged in collaborative meaning-making during a small group science activity. Both videos purposefully examined student-to-student talk within a small group context without adult contributions or interruptions.

5.2.2.1 The emergence of scientific language

The following examines one student's use and understanding of scientific language as it evolved within a social context over nearly a year from prior to the commencement of the programme until mid-way through Phase 3. This student, Shane, was selected as his experience illustrated in detail the complexity of the process of using and understanding scientifically longitudinally over two phases of the programme whereas the other students' examples related to only one phase. Furthermore, this example showed how using scientific language does not always correlate to understanding the scientific concepts. Shane's journey to understand and use scientific terminology occurred during his group's discussion of dissolution. His references to the process of dissolution from the two videos are included.

In the first video, Kelly claimed the jelly crystals "dissolve better in the hot water" (V1). Shane agreed, "Yeah, it feels better in the hot" (V1). Although his statement acknowledged the presence of hot water, his comment about it feeling better in the hot water indicated he might not have made connections between the heat and the acceleration of the dissolving process. This tentative orientation towards the phenomenon of dissolution is further substantiated in the second video when Shane observed the acid dissolving the magnesium tape and stated, "it's dissolving, it's devolving" (V2). He seemed to be uncertain as to the correct terminology to describe the process, displaying confusion between two words that sound the same. Kelly immediately confirmed the correct scientific word as "dissolving" (V2) and Shane repeated it, almost as if he was trying to familiarize himself with it and lock it into his repertoire of scientific words. In his next observation, he referred to the magnesium tape as "devolving" and then quickly self-corrected to say, "it's dissolving" (V2). Later in the experiment, he used the correct terminology in his observation that the magnesium tape was, "dissolving quicker" (V2).

When Shane commented that the magnesium tape was shrinking, Lisa replied, “Yeah, it always shrinks, that’s how it dissolves” (V2). Shane replied, “because it’s dissolving” almost as if this was a continuation, and therefore an explanation, of his previous observation about the tape shrinking. At the conclusion of the experiment, he again used ‘dissolving’, as he talked about the acid and the water “mixing, and if they mix and the magnesium tape’s on the top, they could dissolve into it, dissolve into the middle of them” (V2).

Kelly and Lisa confidently used the term ‘dissolve’ during both the science activities. It needs to be acknowledged during her scientific recount, Lisa used a bridging device (Lindfors, 1999) to help her take a leap into scientific language related to dissolution. This indicated that this particular scientific terminology was not yet consolidated into her scientific language repertoire. In the different context of a group science activity, Lisa was able use Kelly’s unconscious modelling of the term dissolve throughout both activities as a way to support her use of this scientific language. Shane, however, took a different pathway. Although he used the scientific term ‘dissolving’ in his conversation, it was not necessarily used in a way that is consistent with accepted scientific understandings. This was evidenced in his connection of dissolution to feeling better in heat and his confusion between the terms ‘dissolving’ and ‘devolving.’ At times he seemed to have mastery of the vocabulary as demonstrated when he corrected himself after he used ‘devolving’ instead of ‘dissolving,’ and then used the word ‘dissolving’ in his next statement about dissolution. He picked up on Lisa’s idea about the tape shrinking as a result of dissolving as a possible connection to help his understanding. In his final contribution he used the term ‘dissolve’ twice.

In Shane’s last contribution, he talked about the acid and the water “mixing, and if they mix and the magnesium tape is on the top, they could dissolve into it, dissolve into the middle of them” (V2). Shane referred to the acid and water as mixing, but his comments could be interpreted as the acid solution dissolving the magnesium tape, “they could dissolve into it” or the magnesium tape dissolving the acid and water solution, “dissolve into the middle of them.” This could indicate confusion between which substance was the solvent and which was the solute. Even so, he was at least aware that one substance was dissolved by the action of another substance. His comment, “dissolving into the middle of them” may refer to the tape dissolving into the spaces in water and acid solution. He was very aware the magnesium tape was on the surface of the water, as opposed to his prior experiences, such as jelly crystals, where the solute remains mainly at the bottom rather than on the surface. He seemed to be explaining how the magnesium tape dissolved when it was floating on top of the liquid by saying the acid was going into the spaces in the magnesium tape. This contribution demonstrates the multiple, speculative, and emergent ways students struggle to rationalize and articulate aspects of scientific phenomena as they transition from the macroscopic level (magnesium tape is shrinking) towards a more microscopic perspective (one substance dissolving into another).

This illustrates Shane’s personal pathway towards situating the specific scientific term ‘dissolve’ within his ways of looking at and talking about the world. At times, it seems he is not so much communicating his observations, but is more focused on understanding and using the term ‘dissolve’ within the context of scientific discussions. He tried to develop his understanding by seeking connections with the term ‘dissolving’ in his observations and interactions with other group members (jelly crystals feel better in hot water; the magnesium tape shrinks when it dissolves). Throughout the discussions, he used and reused ‘dissolve’ almost as if to familiarize himself with the term. This process of emerging or evolving scientific language is a result of the student exploring both the language and the situation (Roth, 2005b). However, it needs to be emphasized that the situation is more than a small group discussion about their science activities. It also incorporates the social interactions of the group members as they supported and assisted Shane in his quest to consolidate this new language.

These results bring into question whether students acquire or appropriate new scientific language. The acquisition or appropriation of new forms of language implies students construct the necessary language in a linear, sequential cause and effect design. In fact, the use of scientific language evolves or emerges over time. Roth (2005b) uses the analogy of a darkened room to explain students’ emerging scientific language. He maintains children approach new scientific phenomena in the same way that one would explore an unknown darkened room. If one is unsure where one is in the room and if one is uncertain about what the world inside that room looks like, then one would first have to make a careful investigation of the room, even though one is not sure where to begin. In the world of science, students are often not familiar with either the phenomenon under investigation or the relevant scientific language to describe them. The language and knowledge develops together as the students engage with the phenomenon, but in the process students may digress into what adults would consider peripheral areas. In actual fact, the students are attempting to orientate themselves towards this scientific phenomenon, by synthesizing all what they consider to be relevant information before consolidating the new ways of talking about their world.

Based on the evidence in this study, it would be more accurate to describe Shane's increasing use of scientific language as emerging or evolving. His use of scientific language was dependent on a variety of factors including the tension between his prior experience, culture, own everyday language and knowledge (Ash 2004; Roth 2005b; Roth 2005c).

5.2.2.1 Role of language in scientific meaning-making

Language is a vital tool for the communication of scientific knowledge and understandings (Settlage & Southerland, 2007). Vygotsky (1981) claimed the internalization of knowledge was dependent on first the sharing and refining of ideas at the social level before these concepts are understood by the individual. Therefore, students engaged in small group science activities often participate in the "collaborative construction of knowledge" (Anderson et al., 2008, p. 529). The following extract took place during the jelly crystal experiment prior to the commencement of the programme, when the group was discussing the samples of jelly crystals in cold and hot water. It illustrates how each group member contributed to the group discussion in order to build their understanding of what they had observed.

Tom: You can see them dissolving.

John: On the bottom. Those ones are rising, these ones are sinking.

Tom: I know.

John: Well, some of them are.

Jerry: So that means the cold, is that the cold?

Tom: Yeah.

Jerry: Cold water makes the jelly crystals rise.

John: Rise and the hot

Jerry: And the hot makes them sink.

John: Makes them sink. And I think hot dissolves them the most, makes them break up.

Tom initiated the discussion with his observation that the jelly crystals were dissolving. John built on Tom’s observation by describing where the crystals were and what the crystals were doing. Tom agreed with John’s observations whereupon John proceeded to modify his observation to ensure more accuracy. At this stage Jerry entered the discussion making links between what the jelly crystals were doing and the temperature of the water. Tom confirmed it was cold water for this part of the activity at which stage Jerry attempted to explain what the cold water did to the jelly crystals. John reentered the discussion, reiterated the last word Jerry said, ‘rise’ and started to make a comparative statement about hot water. Next, Jerry also reiterated the last words John said ‘and the hot.’ He then expanded and completed Jerry’s comparative statement regarding his predictions as to what he thought would happen with the hot water. Again, John agreed with Jerry by reiterating the last words Jerry said ‘makes them sink’ and extended the thinking further by first, predicting the effect of the hot water on the crystals and second, elaborating on what dissolving does to the crystals.

During this extract, the students displayed a homogeneous pattern of talk, with no evidence of debate, challenge, or disagreement. Tom contributed the initial statement and then interspersed the discussion with two comments displaying agreement and support. John and Jerry extended the homogeneous pattern of talk to that of cumulative talk (Berne, 2014; Mercer, 2004) whereby they unconditionally accepted and built on the previous speaker's contributions as a way to develop a shared meaning of what they had observed.

Tom and John both used the scientific term 'dissolving' during the discussion, with John engaging in a double talk discursive structure by giving an alternative version of dissolving as, 'makes them break up." This use of scientific language could give the impression that these students understand what dissolution is. However the middle section of the discussion focused on whether the crystals were rising or sinking, as opposed to aspects of dissolution. Consequently, it is unlikely that the students' use of scientific language did indicate a complete understanding of dissolution. This does not mean the students' theorizing was necessarily wrong. It could have been influenced by the teacher-imposed goal, that is, to find out whether jelly crystals dissolved faster in hot or cold water. This may have encouraged the students to focus primarily on the temperature of the water. The focus on the crystals rising and sinking could be attributed to the students commenting on the most noticeable or the most immediate aspects. From their perspective, perhaps the rising and sinking of the crystals occurred before any dissolution. What is apparent however is that these students did not initially perceive the phenomenon the same way as the teacher. Therefore, the students were engaged in developing an understanding commencing from their own orientation of the world, not that of an adult.

The jelly crystal extract with Tom, Jerry and John illustrates Roth's (2005b) analogy of a darkened room discussed earlier. Even though the students were familiar with the making of jelly in everyday life, they explored the phenomenon of dissolution in a seemingly haphazard way, focusing on rising and sinking of the jelly crystals in different temperatures of water before coming to what in some ways seems a tentative statement about dissolution occurring faster in hot water. To an adult, it would seem that the students demonstrated a "conceptual muddle" (Roth, 2008, p. 36) by focusing on the suspension of objects in water with the dissolution of objects in water. In fact, they were engaged in a process where they "came to orient, perceive and speak in increasingly similar ways" (Roth, 2005b, p. 80) about the phenomenon under observation.

It is interesting to note John's use of the "I think" structure. This type of discursive structure in science discussions can indicate several different propensities (Varelas, Pappas & Rife, 2006). It may indicate the speaker's confidence in verbalizing his or her own thoughts in the public arena, and the willingness to involve others in debate and discussion. Or, it may indicate that the speaker's ideas are speculative and open to modification by others. Furthermore, it may indicate the speaker is unsure and hesitant about their contribution. The student talk in this example was homogeneous in nature, with the students building on each other's contributions and exhibiting no evidence of debate or opposing viewpoints. It would therefore follow that John's use of the "I think" structure indicates his predictions are tentative and open to changes or slight modifications by the listeners similar to the pattern that had already occurred in this discussion.

We now proceed to examine the language within a group meaning-making context that occurred towards the end of the programme in order to establish if there was any change over time as a result of their experience with the Chemistry Outreach programme. This group consisted of Jerry and Tom with their new group member Peter. The extract takes place at the end of the magnesium tape experiment where the students were required to answer two questions. The focus of the activity was to observe the rate at which magnesium tape dissolved in different concentrations of water and hydrochloric acid. It is of note that this extract is much longer than the previous one, possibly indicating the students' growing confidence to sustain longer discussions as they share and shape their ideas within a social context.

Peter: [reading the question] OK, what happened as you added more water?
Jerry: I reckon it made the bubbles come up faster.
Tom: And it takes longer to dissolve.
Peter: I reckon the water had something to do...
Jerry: with less acid, um
Peter: Yeah, with less acid it makes it...
Jerry: The water takes over and it makes it stay for longer.

Peter: And, yeah.

Tom: It takes kind of longer too ... in the ten mls [of water] it took almost a minute, and then in 20mls of water it got past a minute. So I reckon more water makes it longer to dissolve.

Peter: I reckon it's [the water's] affecting the acid.

Tom: Cause and the acid, less acid and more water makes a big difference.

Peter: And, um, the water is taking over.

Tom [reading the question] OK, what's the next one? What is the water doing?

Peter: Um, oh...

Tom: Oh, it's affecting the acid, so...

Peter: Yeah, it's stopping the acid to...

Tom: From making it's path.

Peter: Yeah, it's stopping the acid destroy the magnesium tape. So it takes longer and then...

Tom: The water loves the magnesium tape, the acid hates it.

Peter: So, it's like the water's holding the acid off, and then where it's trying to get past it, it breaks the magnesium tape after a while.

Jerry: Yep, I agree with you Peter.

Peter: Yeah so, the last one it's like the water was stopping the acid from getting through to destroying the tape and then after a while it gets through ... the water's heavier ... or it could be that ... water's just water and acid, it kind of breaks up stuff.

Peter initiated the discussion by reading the question requiring the students to consider the effect of adding more water to the acid. Jerry was the first to contribute, indicating that the effect could possibly have something to do with the speed of the bubbles. Tom's contribution about the length of time for the tape to dissolve built on Jerry's idea, as evidenced by his use of 'and' at the beginning of his statement. Peter then proceeded to offer another possible explanation, " I reckon the water had something to do ... " and when he hesitated to consider his thoughts, Jerry added, "with less acid." Peter agreed with Jerry's offering, and started to develop further the possible effects of less acid. When Peter paused, Jerry picked up on the idea of less acid and suggested two possible effects: water taking over, and the tape staying longer in the solution. Peter was going to add to this idea as evidenced in his use of ‘and’ but then settled with an indication of agreement with Jerry’s idea. Tom re-entered the discussion, reiterating Jerry’s idea about taking longer, but slightly modifying it from the tape staying longer to the tape taking longer to dissolve. He then gave evidence of the length of dissolution times compared to the different concentrations of acid and water gathered during the experiment as justification for his conclusion, “so, I reckon more water makes it longer to dissolve.” Peter picked up this idea and gave a possible reason as to why more water resulted in a longer time for the tape to dissolve, “I reckon it’s affecting the acid”. Tom was going to offer an explanation for water affecting acid as evidenced by his use of ‘cause’ at the beginning of his contribution but changed his mind and added a comment which summarized the ideas which had already been discussed. Peter’s explanation for Tom’s summary of less acid and more water making a big difference was a reiteration of Jerry’s earlier contribution of the water taking over.

The second question asked the students to discuss what the water was doing. Peter started to answer but when he paused Tom took the lead and continued with the idea of water affecting the acid. The group had been talking about this idea towards the end of the discussion of the first question. Tom’s contribution ended with a ‘so’, indicating an explanation may follow. When Tom paused, Peter agreed with Tom’s contribution and proceeded to add to Tom’s 'so' by offering an explanation, “it’s stopping the acid to...” which Tom finished, “from making it’s path.” Peter agreed with Tom’s contribution and then proceeded to reiterate his previous comment, “it’s stopping the acid.” This time he gave a possible explanation as to what the water was stopping the acid from doing and then linked it to the length of time for dissolution. Tom then used the creative literacy device of personification to help him towards theorizing, “the water loves the magnesium tape, the acid hates it.” Peter built on his own previous idea of the water stopping the acid from affecting the magnesium tape and Tom’s idea of the water loving the magnesium tape to theorize that the water was holding the acid off the tape and the acid can only affect the tape if it gets past the water. Jerry re-entered the discussion to indicate his agreement with Peter’s idea. Peter acknowledged this confirmation with a ‘Yeah.’ He then said so, indicating that he was going to give an explanation. However, before he gave his explanation he restated the idea that water was stopping the acid from affecting the magnesium tape. Then he gave two possible explanations, "the water's heavier ... or it could be that ... water's just water and acid, it kind of breaks up stuff." In this extract, the students continued with the pattern of cumulative talk (Berne, 2014; Mercer, 2004) evident in the first extract. Cumulative talk involves the construction of meaning-making through the accumulation of ideas presented within the group. This type of talk is dominated by the discursive features of "repetitions, confirmations and elaborations" (Mercer, 2004, p. 146). The statements or phrases from the previous speakers were unreservedly accepted and/or added to by the present speaker, often without discussion, debate or challenge. The students used the discursive strategy of revoicing as a way to acknowledge and validate the previous speaker's contribution and further extend and at times clarify their thought processes to continue the process of co-construction of meaning (Collins, Palincsar & Magnusson, 2005). To illustrate, Peter contributed ten comments to the discussion, with five prefaced by 'yeah', 'oh yeah' or 'yep' indicating agreement and/or acceptance of the previous speaker's comment. There were four instances where a comment that added or extended the previous speaker's ideas followed the affirmation of the previous speaker's contribution.

Tom's use of "the water loves the magnesium tape, the acid hates it" is an example of the use of a creative device which can help students "make the intellectual leap toward theory" (Gallas, 1994, p. 102). Tom was aware that he had some knowledge about the phenomenon under observation and although this knowledge was incomplete he still attempted to theorize using an image that resonated with him. The use of analogy, metaphor, and personification can help students articulate difficult ideas that they may find difficult to express in everyday language and in doing so can assist in developing students' thinking towards more complex reasoning (Gallas, 1994, 1995).

These discussions were conducted in a positive, inclusive way, with contributions linking in with and developing previous ideas. This resulted in the sharing, shaping and defining of the group's ideas as they converged towards a common understanding. The majority of utterances were not spoken of as definitive facts but of possibilities and suggestions, underscoring the tentative nature of the discussion. The 'I reckon' structure used by all the students in this extract is similar to the 'I think' structure illustrated in the previous extract. It indicates a tentative prediction and invites acceptance and/or modification from the other group members. The 'or it could be' structure in Peter's last contribution "the water's heavier ... or it could be that water's just water and acid, it kind of breaks up stuff" has a similar function. He offered several suggestions for the explanation and in doing so is opening the discussion up for group comment. The halting speech patterns indicated by the ellipses in the transcriptions show the students were uncertain and tentative about their theorizing, but still felt confident enough to articulate their thoughts, wonderings and semi-formed theories within the public arena.

At no stage did the students ask themselves or an adult if they were right, indicating they were not seeking a definite conclusion or closure to their discussion. Instead they were focussed as a group on inquiring further about the phenomenon under investigation. Gallas (1995) refers to these types of discussions as forming a shared territory for the group members where they can confidently co-construct scientific understandings. Such collaborative discussions can provide the opportunity for:

> all children [to] feel the power of collaborative theory building and in fact understand the excitement of building a theory, *even if it is an incorrect theory.* Incorrect theories are better than no theory at all! Incorrect theories are better than silence! Incorrect theories are, in fact, often the basis for correct and revolutionary theories in the field of science (Gallas, 1995, p. 99, italics in the original).

Therefore, although scientific language was not so apparent during the investigative science activities, scientific meaning-making was evident. New scientific understandings were co-constructed between speakers and listeners over time. In other words, as the students engaged in the science activities within the social context of a small group, they talked the science into being (Gallas, 1995; Lemke, 1990; Siry et al., 2012).

5.2.3 Discussion of Scientific Language Results

This study has shown how the Chemistry Outreach programme positively affected students' use of scientific language. The transition from everyday talk to more scientific language evidenced in most of the students' oral recounts during the third focus group interviews can be attributed to the Chemistry Outreach team who regularly used "double talk " (Brown & Spang, 2008, p. 708). This is a combination of everyday and scientific language to provide clarity of scientific terminology, ideas or concepts. The results from this study confirm other research findings, which indicate an increase of the use of scientific language when students are exposed to this hybrid mode of scientific and everyday language (Brown & Spang, 2008; Roth, 2005b; Varelas et al., 2006).

An interesting anomaly that occurred in the results was one student who did not use any scientific language throughout the interviews. Although Peter used everyday language he was still able to convey his developing understandings of a complex scientific phenomenon. This finding challenges Gee's (2004) assertion that everyday language is a liability in scientific classrooms. Despite not using scientific language, Peter demonstrated that he was capable of thinking scientifically as he attempted to make sense of a complex phenomenon. This confirms the view that everyday language is the first step in the process of the emerging use of scientific language, and therefore can be viewed as an asset in the classroom (Lemke, 1993; Roth, 2005b, Varelas et al., 2006; Wallace, 2004).

The emerging use of scientific language was further explored in Shane's attempts to use and understand scientific vocabulary related to dissolution within a small group setting. As the group engaged in the collaborative construction of meaning-making about dissolution, Shane transitioned back and forth between everyday language and scientific language in his attempt to reconcile his prior knowledge, culture, everyday language and knowledge (Pickering, 1995; Roth, 2005b; Roth, 2005c). The findings from this extract are consistent with the considerable research literature that claim students' exposure to and/or use of scientific vocabulary does not automatically equate to an understanding of the terminology (Marshall et al., 1991; Meyerson et al., 1991; Milne, 2001; Pickersgill & Lock, 1991; Skamp, 2015; Wellington & Osborne, 2001; Wenham, 2005). Furthermore, Shane's initial confusion between the terms 'dissolving' and 'devolving' echoes research findings that found students often showed confusions between scientific words that sound the same (Marshall et al., 1991). Although his group members modelled the correct scientific terminology, Shane's attempts to use scientific language highlight the fact that exposure to a scientific term does not automatically equate to accurate usage within scientific discussions. Rather, it contributes to the view of scientific language as a process where the student develops understanding and ability to articulate scientific conceptual ideas in everyday language first before using scientific language (Lemke, 1990; Roth, 2005b; Varelas 2006; Wallace, 2004). Throughout this process, the student, as Shane did, may transition back and forth between everyday language and scientific language (Moje et al., 2004).

This process was also evident during the investigative science activities within small group settings, where the students used mainly everyday language whilst collaboratively constructing meaning. Wallace (2004) describes the student voice in these multiple discourses as ranging "from private genres of speculation and questioning to public genres of evidence-based science that has the authoritative voice of the scientific community" (Wallace, 2004, p. 911). As the students concentrated on co-constructing meaning within a science activity, they talked science into being using mainly their everyday language (Gallas, 1995; Lemke, 1990; Siry et al., 2012). This supports the Vygotskian perspective that scientific language primarily emerges within the social context, in this case, the small group setting, before becoming part of the individual student's way of thinking and talking.

The findings show that everyday language and scientific language need not be dichotomized but can be regarded as integral parts of the process of the communication in science (Ash, 2008; Brown & Spang, 2008, Rahm, 2003). Furthermore, this study has highlighted the interrelationship between language and meaning-making in social contexts, whereby new scientific understandings are collaboratively constructed through discussion within the context of hands-on activities (Gallas, 1995; Lemke, 1990; Siry et al., 2012).

The results from this study contribute to the debate regarding students' use of everyday and scientific language and the resulting pedagogical implications (Ash, 2008; Roth, 2005b; Varelas et al., 2007). The Science Achievement Aims in *The New Zealand Curriculum* (Ministry of Education, 2007) state students will develop knowledge of scientific vocabulary, numeric and symbol systems, and use this scientific language to communicate scientific ideas and concepts. The specific expectation for the students in this research study is that they will "begin to use a range of scientific symbols, conventions, and vocabulary" (Ministry of Education, 2007, Science Achievement Aims, Level Three and Four, paragraph 3). Teachers assess students' capabilities in using scientific language (see Appendix H for an example of an assessment rubric for scientific language used by the schools in the same Professional Development contract as the researcher). Anecdotally, teachers are likely to infer that students who quickly acquire and use scientific language are often regarded as having considerable talent and skills as a science learner. However, this was not the case for all students as evidenced in Peter's explanation of a complex phenomenon in everyday language. The results from this study indicate it is important that understanding precedes the use of scientific language, as understanding does not exist in the terms but the conceptual knowledge and understandings. The Chemistry Outreach programme offered a supportive discursive learning environment where first, students were scaffolded into the ways of scientific thinking and talking, through the use of everyday and scientific language and second, students had multiple opportunities to talk their scientific understandings and knowledge into being within a social context (Gallas, 1995).

Chapters Four and Five have examined the influence of the Chemistry Outreach programme on the students' attitude towards school science, engagement with school science, as well as the use of scientific skills and language. Chapter Six will now proceed to examine the culture of this rural school and the Chemistry Outreach programme with the culturally responsive considerations outlined in *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011).

CHAPTER SIX
RURAL PRIMARY SCHOOL SCIENCE

6.0 Introduction

The previous two chapters explored the influence of the Chemistry Outreach programme on the students' attitude, engagement, scientific skills, and scientific language. The discussion of the findings revealed underlying factors that had the potential to affect the students' experience of the science education. These factors are consonant with the competencies inherent in *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011). Competencies "are about knowing, respecting, and working" alongside students and their whānau/family, so "their worldview, aspirations and knowledge are an integral part of teaching and learning, and of the culture of the school" (Ministry of Education, 2011, p. 4). Included in the Tātaiako competencies are ako (teaching and learning), whanaungatanga (building relationships), manaakitanga (values - integrity, trust, sincerity, equity), tangata whenuatanga (placed-based, socio-cultural awareness and knowledge), and wānanga (communication, problem solving and innovation). Although these competencies are categorized as five separate entities, in reality the parameters between them frequently overlap. The following indicates how the factors are consonant with the Tātaiako competencies.

The students' attitudes to the Chemistry Outreach programme were influenced by their emotional connectedness with the programme and relational connectedness with the scientists. Consequently, the students' favourable responses to the Chemistry Outreach programme were a result of the scientists as teachers who were passionate about science and made science fun, and enjoyable (ako), and the learning environment they created through supportive, reciprocal relationships (whanaungatanga) that incorporated the values of trust, care, and humour (manaakitanga). Factors that influenced the students' enagement with the science programme included the scientists' expertise (ako), the authenticity of the programme (tangata whenuatanga), and the opportunity to actively participate (wānanga). Positive influences on the students' scientific skills were the inclusive group work format (whanaungatanga), the use of peers as teachers (ako), and the practical hands-on aspects of the programme (wānanga; tangata whenuatanga). The students' use of scientific language was influenced by the provision of a discursive group environment that encouraged collective problem solving and co-construction of scientific ideas (wānanga).

This research is situated firmly within the context and as a result the culture of a very small two-teacher New Zealand rural primary school. As a result, the school's rural micro-culture is influenced by the macro-culture of Aotearoa[14] New Zealand. New Zealand is a bicultural society, which acknowledges the cultures of the indigenous Māori as well as the European settlers. Of particular interest to this study are the similarities between the culture of this very small school's rural community to the Māori culture. Both cultures have a strong affinity with the land through historic, economic, recreational, and social links. Both communities are very interested in the stewardship or guardianship of the land for the present and future generations. There is a strong sense of belonging within the Māori community and this rural community where education is seen as a collective rather than a personal endeavour. This similarity reinforces the use of Tātaiako as an appropriate approach way to understand education for rural learners.

There are concerns about the persistent underachievement of Māori students in comparison with other students in Aotearoa New Zealand (Crooks & Flockton, 2000, 2001; Ministry of Education, 2002, 2009, 2011, 2013a). As a result, the Ministry of Education have produced a series of publications for teachers emphasising effective pedagogy focused on Māori students achieving educational success as Māori. These include, but are not limited to *Ka Hikitia: Accelerating Success 2013-2017* (Ministry of Education, 2013a), *Ka Hikitia Managing for Success: The Māori Education Strategy 2008-2012* (Ministry of Education, 2009b), and *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011). These publications seek to enhance student learning through more culturally appropriate teaching and learning approaches which are variously referred to as: culturally responsive teaching (Gay,

[14] Aotearoa is the Māori name for New Zealand

2000); culturally responsive pedagogy (Glynn, Cowie, Otrel-Cass & MacFarlane, 2010); culturally responsive pedagogy of relations (Bishop, Berryman, Cavanagh & Teddy, 2009); or culturally based pedagogy (McKinley, 2005).

Anecdotally, many New Zealand teachers use the pedagogical principles inherent in these publications as guidelines for effective classroom practice to ensure that not only Māori students but *all* students realise their potential and succeed. Personally, I have recently incorporated the *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011) with the New Zealand Registered Teacher Criteria (New Zealand Teachers Council, 2010) when I updated my present school's annual Teacher Performance Management and Appraisal Document, even though there are no self-identified Māori students on the roll.

As already indicated, the research school under investigation has a unique culture. In this instance culture does not relate to ethnicity or race but refers to the ways of knowing and doing that are specific to this certain group (Berryman, Walker, Reweti, O'Brien & Weiss, 2000). Inherent in the concept of culture is "the worldview created, shared, and transformed by a group of people bound together by a combination of factors that can include a common history [and] geographical location" (Nieto, 2000, p. 139). Therefore, this rural school's culture is influenced by the values, beliefs, and practices that the students are exposed to and influenced by through living within this rural community.

The underlying factors of influence are discussed in relation to the competencies outlined in *Tātaiako: Cultural Competencies for Teachers of Māori Learner* (Ministry of Education, 2011) and aligned with the cultural setting of the rural primary school in this research. In taking this approach, this research does not promote a deficit theorizing approach to rural science education that regards students as being disadvantaged or marginalised because of their location and background. Rather, it emphasises the intrinsic importance and value placed on the lifeworld of these rural students, which includes their experiences and histories of the local school, their immediate family, the local community, and the rural environment. Therefore, effective science pedagogy takes into account "knowing, respecting and valuing who students are, where they come from and building on what they bring with them" (Ministry of Education, 2009b, p. 20). The following discussion explains each of the competencies, and describes the relevant aspects of the rural community culture and the culture of the research school under investigation in relation to the competencies. It then discusses the findings in relation to this specific school's rural culture and the Chemistry Outreach pedagogical practices within the framework of each of the culturally responsive competencies outlined in *Tātaiako: Cultural Competencies for Teachers of Māori Learner* (Ministry of Education, 2011). The data from the parents' and community members' interviews were used to describe the community culture in addition to my own observations of the school culture as teacher researcher. Aspects of the community's culture that were spoken of by most of the adult participants were included in the text and were coded as Parent (P) and Community member (CM). Any other reflections on the community culture are prefaced by "I found" to indicate they are my personal observations.

6.1 Ako

Ako relates to the practices in the classroom that incorporate the components of effective learning, pedagogy, and curriculum to ensure students reach their potential (Ministry of Education, 2011). It combines aspects of both teaching and learning as ako has the dual meaning of "to learn as well as to teach. It is both the acquisition of knowledge and the processing and imparting of knowledge" (Bishop & Berryman, 2009, p. 31). This reciprocal teaching and learning relationship where the teacher is also the learner and the learner is also the teacher is an integral part of ako. It means the teacher does not always have to take on the role of the expert who transfers knowledge to the students but is more of "a partner in the conversation of learning" (Bishop & Glynn, 2000, p. 4).

The reciprocal teaching and learning principle of ako is embedded in the life of this particular rural community. The adults are regularly involved in the sharing of knowledge and learning from other adults, often across generations. Many of the farmers belong to the local farm discussion group which meets regularly to discuss new farming ideas, products or practices (CM5; P1). This sharing of knowledge between adults is also present in informal sharing contexts. To illustrate, I found the monthly School Board of Trustees meetings were always preceeded by the Board members, who are all farmers, discussing and comparing the effects of the recent weather, current stock prices, etc. on their farming practice.

Knowledge sharing betwen adults and children is very common in this community. Many of the parents were involved in sports in their youth and are now keen to pass their skills onto their children, and in some cases, coach school sports teams in a variety of sports (P3; P16). Although these children are very proficient at accessing information through the internet, it was noticeable that the transfer of farming knowledge to the younger generation is predominantly through the adults, in particular their parents, and older siblings. The children are all involved in the day to day aspects of farming. In fact, it is expected that they would participate in farming tasks such as lambing[15], tailing[16], woolhandling[17], crutching[18], and mustering[19]. These farm tasks are labour intensive, and often farmers would work in with other farmers, rather than employing extra labour, in order to accomplish these tasks. To illustrate, a farmer would assist with tailing on other farms and then the farmers he had worked with would help him with his tailing. As mentioned, this was a family effort with all the children expected to help. The children work alongside the adults learning these basic farming skills (P9; CM1). This entails learning on the job, or an active learning approach, where the processes of knowledge-in-action are able to be put immediately into practice. This learning approach is also used by the adults to teach the children recreational skills such as hunting on the farm for rabbits and ducks, and fishing in the local river for trout (P10; CM5). The reciprocity of the ako concept is apparent in the knowledge sharing between child and adult where children as teachers teach their parents some of the skills they had gained at school, in particular numeracy strategies and information technology (P7; P11).

[15] Lambing refers to when female sheep give birth to lambs.
[16] Tailing is the shortening of the lamb's tail to prevent soiling.
[17] Woolhandling is the grading of the fleece wool after it has been shorn from the sheep.
[18] Crutching is the removal of the wool from around the tail and between the rear legs of a sheep.
[19] Mustering is gathering in livestock usually into sheep yards or holding paddocks.

The concept of ako is very evident in the culture of this very small rural school, for instance, the children taught me, as their teacher, the finer points of competitive rugby, cricket, hockey, and netball. The school embraces the core tikanga Māori concept of tuakana-teina, a form of ako (Grazier & Meade, n/d), which involves the tuakana (older sibling) and the teina (younger sibling), and is specific to teaching and learning (Te Whāiti & McCarthy, 1997). In the educational setting the older or more expert child guides the learning of younger or less expert child. At this school, tuakana-teina occured within each classroom and between the two classrooms. This mentoring buddy system reflects the reciprocal aspect inherent in the ako concept where the child who may be the expert one day, may learn from his or her classmates the following day.

Within the context of the Chemistry Outreach programe, ako refers to the "use of strategies that promote effective teaching interactions and relationships with the students" (Bishop, Berryman, Tiakiwai & Richardson, 2003, p. 106). As already shown, the teaching and learning culture of this rural community is very much a partnership where adults and children share knowledge. There are teaching and learning strategies apparent in this rural culture that were similar to those used in the Chemistry Outreach programme.

Although there was some whole class instruction prior to the students' involvement in the science activities, the organisation of the Chemistry Outreach programme predominantly involved small group and/or partners engaged in putting the processes of the knowledge-in-action into practice through hands-on activities. Knowledge gained in the smaller settings was reported back to the class. This active learning approach enabled the sharing of knowledge from adult to the students as well as between students in a cooperative learning context, similar to that experienced by the students on the farm and in the home. Cooperative learning has been identified as a valuable teaching and learning approach (Brown & Thomson, 2000), which is ranked as more effective than hetergeneous classes, individualistic learning, and competitive learning (Hattie, 2012). This highlights the social nature of learning and the powerful influence of others in the learning situation (Kelly & Crawford, 1997; Varelas et al., 2007; Vygotsky, 1981).

The reciprocal teaching and learning inherent in ako is promoted through the use of cooperative learning. The learning moves away from the expert-novice model to a situation where the learning and teaching positionings are fluid and interchangeable (Glynn et al., 2010). This was evident in the teaching and learning roles within the scientist/s-student/s, student-student/s and students-community interactions during the programme (see Appendix A).

The roles of the scientists as teachers and the students as learners changed over the duration of the programme. As the programme progressed from a structured to a more open scientific inquiry format, the scientists and students worked along side each other in an equal power-sharing interaction. The scientists freely admitted to the students that they had not previously investigated the students' scientific questions. This meant the scientists were not experts in this area as they did not know the outcomes of the students' investigations. Therefore, the students and scientists were involved in a reciprocal co-learning situation where knowledge was created through cooperative learning. Both the students and the scientists expected to benefit and learn from this relationship.

When students are engaged in cooperative learning, "they are more likely to focus on learning, are more interested in the subject matter and feel less anxious" (Cushman & Rogers, 2008, p.15). Working alongside the scientists made the students feel very grownup and important, and they felt this working partnership gave their student-directed investigations an air of credibility. They felt they were on an equal footing with the scientists. This meant there was a decreasing power advantage usually held by adults, resulting in less dominance over the students. The students were more receptive to initiating interactions with the scientists that went further than the clarification of instructions to knowledge construction through student generated questionings and wonderings. As a result, the students took more ownership and leadership of their own learning.

Teaching and learning within the student-student/s interactions involved tuakana-teina where the more knowledgeable student/s assisted the less knowledgable. This knowledge sharing amongst the students was particularly evident towards the end of the programme, as group members showed others how to complete procedural tasks such as accurate measuring and timing for the magnesium experiment. It was further illustrated by Lisa and Kelly, who took on the role of teacher when they were assisting Shane in his developing understanding of the concept of dissolution. Peers can have significant positive effects on students' learning as revealed in Hattie's (2009) synthesis of studies of peer influences on student learning. When a student learns from another student, there are positive effects for both the student who is the teacher, and the student who is the learner (Hattie, 2012). Students often consider learning from other students is easier and more fun (Pickens & Eick, 2009). Peer mentoring contexts help the students transition from students to being their own teacher and a teacher of others, further enhancing the control and ownership over their own learning (Hattie, 2012) .

Ako views teaching and learning as interlinked, and that knowledge gained by individuals need to be shared with others (Cowie et al., 2011). The students had an opportunity to take on a teaching role with the adults when they shared their scientific investigations with the community. The community members were very receptive to learning from the students, particularly because the topics the students had selected, water and soil nutrients, were topical issues for the farmers at that time. The handing over of the teaching role to the students within an adult learning context redistributed the usual adult-child power relationships inherent in many teaching and learning contexts. This power sharing can make the students feel empowered in their learning as they feel they are regarded as knowledgeable contributors in this subject area, and therefore their investigations are taken seriously.

Knowledge sharing amongst and between adults and children is very much embedded in the culture of this community. The teaching and learning strategies used within this rural community's culture involving interchangeable learning and teaching positionings between adults and children were also used within the Chemistry Outreach programme, and served to consolidate and increase the students' and the community's knowledge, and as a consequence, the well-being of the community.

6.2 Whanaungatanga

Whanaungatanga refers to the building of extended whānau family-like relationships where individuals work together towards a common purpose of the group (Bishop, Ladwig & Berryman, 2014). The focus is not on individual independence but rather interdependence with members of the larger group. In other words, the collective has primacy over the individual. However, this does not mean that the individual is powerless within this group situation. Whanaungatanga encompasses "knowing you are not alone and that you have a wider set of acquaintances that provide support, assistance, nurturing, guidance and direction when needed" (Williams & Broadley, 2012, p. 5). This engenders in the individual a sense of inclusiveness and belonging to the larger group.

The concept of whanaungatanga is evidenced in the community by the strong sense of inclusiveness and belonging connecting the members to the larger collective whole that constitutes this rural community. The majority of the residents live on well-established family-owned farms, hence this community is not subjected to great changes in the population (CM1; P5). Any new families to the district are welcomed to the community with the school used as the meeting place. All the families in the school know each other and regularly socialize together out of school hours (CM10; P15). The children are on a first name basis with all the adults.

I found an integral part of this community's culture is the commitment to out of school sports activities. The majority of the school students participate in competitive team sports out of school hours. All the research students participate in competitive team sports, mainly rugby, netball, hockey, and cricket, which involves at least one practice a week and a competitive game in the weekend. Many of the parents in this community are also personally involved in competitive sport, and are very active supporters of their children's sporting events (P3; CM7). Participation in extracurricular team sports teaches children important social working relationship skills such as a strong work ethic, perseverance when things become hard or difficult, strong teamwork where all group members work together to achieve a common goal, and effective communication within a group setting (Snellman, Silva, Frederick & Putnam, 2015).

Small schools frequently describe their schools as having a whānau or family-like culture, and hence their classroom as a whānau or family of learners (see www.ero.govt.nz for small schools' descriptions of their culture). This concept of family/whānau of learners, or community of learners as reported in research literature (Ash, 2008; Varelas et al., 2007) acknowledges the social aspect of learning whereby learning takes place within a social realm through participation in communities of practice. This means "learning occurs as people participate in shared endeavours with others, with all playing active but often asymmetrical roles in sociocultural activity" (Rogoff, 1994, p. 209).

There is an extended whānau or family-like culture within this school, but not simply because there are siblings in the same class. Rather, there is a strong emphasis on working together as a team, with students encouraged to interact with all students in the school, no matter the age difference. This develops a climate of commitment and connectedness within the group, and a collective responsibility to help others with their learning. The students readily help other students in the classroom, either encouraged by the teacher in a more formal peer mentoring (tuakana-teina) approach or informally when they see the opportunity to help a classmate with instructions or aspects of their learning. There is a culture of celebrating others' work and successes either in class, between classes, or with the community through assemblies and school community newsletters.

Within the context of the Chemistry Outreach programme whanaungatanga refers to the active engagement in building respectful working relationships between scientists and students, and strong connections between the scientists, the students' family and the community (Ministry of Education, 2011). It includes the respect for other's cultures and the feelings of inclusiveness and belonging within the group.

An awareness and respect for each other's culture was shown by both students and scientists. The students acknowledged and appreciated the expertise of the scientists when it came to scientific knowledge. The scientists reciprocated this respect. They did not profess to be experts with regards to rural practices and were willing to be guided by students' knowledge, advice, and guidance. This respect was demonstrated during the sample gathering stage of the students' science investigations when the scientists and students were accessing farm water and soil samples. The students taught the scientists how to climb barbed wire fences safely, and to cross a paddock with lambing ewes without mismothering[20] the ewes and lambs.

The scientists displayed humility and openness towards the students, aware of their limitations as urban scientists operating within a rural world. They used this as an opportunity to encourage the students to share aspects of their rural life, for example when the students described their farm locations and descriptions of duck ponds, water troughs, streams, and cow paddocks as contexts for their investigations.

The feelings of inclusiveness and belonging so apparent in the community were also extended to include the scientists. They attended one of the school's barbeques and participated in a game of cricket with the students. Furthermore, they were invited to the end of year concert attended by the parents and community members where the students presented their science investigations. The scientists discussed the programme and their reflections of the students' participation before awarding certificates to the students. At the end of the concert, the scientists encouraged parents and community members to participate in some of the 'wow' activities the students had experienced at the beginning of the programme, such as lighting one's hand on fire. This also gave the parents and the community the chance to share with the scientists how their children had responded to the programme and their own thoughts as to the value of the programme for their children.

The scientists reciprocated by inviting the students to participate in science activities at a university chemistry laboratory. This combined with the collaborative way the students

[20] Mismothering is when a lamb is separated from it's mother and becomes lost.

and scientists worked on the student-directed scientific investigations helped to engender feelings of togetherness and a focus of working together to achieve a common goal.

The relationships that developed over the duration of the Chemistry Outreach programme did not involve merely a matter of establishing rapport. In fact, these relationships were built and nurtured over a period of time with the focus on the students' well-being and learning. The relationships were not just related to the students, that is to say student-scientist and scientist-student; student-parent and parent-student; student-community and community-student. The relational connections also involved interactions between the adults: scientists-parents and parents-scientists; scientists-community and community-scientists. These reciprocal relationships within the context of this learning whānau or community illustrate the inter-connected web of shared communal relationships that occur within everyday experiences (Palmer, 1998). As teaching can be regarded "at heart [as] a relationship … and everything else depends upon and flows from that relationship" (Tate, 2007, p. 7), the emphasis is on respectful, connected relationships focused on nurturing the wholeness of the student and their learning (Giles et al., 2012). The scientists' commitment to the students' learning along with the connections with the students, their families, and the community engendered a collective responsibility for the students' learning.

6.3 Manaakitanga

Manaakitanga is about the ethic of caring for others and involves the values of "integrity, trust, sincerity and equity" (Ministry of Education, 2011, p. 16). The concept of manaakitanga involves "Mana [which] refers to authority and aki, the task of urging someone to act" (Bishop & Berryman, 2009, p. 30) and in the educational context relates to the building and nuturing of a supportive, loving environment where the students are cared for as "culturally-located human beings above all else" (Bishop, Berryman, Cavanagh & Teddy, 2007, p. 737) in order to empower students to achieve their potential. This culturally-located view of caring further develops the ethic of care espoused by educational writers such as van Manen (1991b) and Noddings (2005) to include caring about the student’s cultural background, as well as their personal capabilities, and learning (Bishop et al., 2014). It is not about self-promotion but about acknowledging the best in others and looking for constructive ways to encourage them to achieve their best (Williams & Broadley, 2012). It is through open and trusting relationships involving manaakitanga values that the teacher and students recognise and acknowledge the knowledge, heritage, and expertise of each student’s family and community.

There is a strong feeling of care and concern for the well-being of community as a whole, with most parents involved in the local volunteer fire brigade, and the organisation of regular community social events especially during the winter months which can be difficult times for farmers (P4: P3). This caring support is also evident for individuals within the community, as demonstrated in fund-raising events for a local sick child. I found the community caring attitude is extended to the school context as well, with a strong involvement in the school’s Parent-Teacher Association, school fundraising events, and assistance with school curriculum activities.

The manaakitanga principles of care and goodwill towards others is evident in the school context. As already indicated, the school community know each other very well. Parents trust other parents to take care of their children. It is quite common for parents to arrange for their children to get off the bus after school at a friend’s place to play, or be transported by another parent to sports events. Parents volunteer transport for day trips to sports and other school events in order to reduce costs. It is normal practice in this community for drivers to text the parents of the children allocated to their vehicle and deliver these children directly to their home after the event, rather than bringing them back to school to travel home by bus. This is indicative of the kindness and consideration shown to each other within this community.

The principle of manaakitanga is apparent within the school culture driven by the community-chosen school values of respect and responsibility for oneself, others, and the environment. The older children look out for the welfare of the younger children in the playground and in the classroom context. There are instances when this caring is reciprocated, for instance, younger children are quick to get adult help should an older child hurt themselves in the playground. These mutually beneficial and reciprocal nurturing relationships engender an emotionally safe environment where the students are very protective of each other and are concerned about each other's personal well-being.

Within the context of the Chemistry Outreach programme manaakitanga refers to the ways the scientists showed they cared for the students by developing and nurturing a caring, supportive learning environment for the students (Bishop et al., 2009). The students spoke at great length of the relational and emotional connectedness they considered had developed between them and the scientists, and the science programme. The scientists-students relationship that developed over the duration of the programme was based on the co-construction of the values of respect and sense of belonging (whanaungatanga), as well as integrity, trust, sincerity, and equity (manaakitanga).

The value of integrity "involves being honest, responsible, and accountable and acting ethically" (Ministry of Education, 2007, p. 10). The scientists encouraged and modelled this value to the students throughout the programme. To illustrate, the scientists taught and encouraged the high standards required for trustworthy data gathering and analysis such as the accurate measuring with the bottom of the meniscus on the measuring line, and the honest reporting of data even though it does not make sense with what they thought would happen. Furthermore, the scientists were honest with the students, letting them know that they had not previously investigated the students' scientific questions, and therefore, by inference, were not experts in this area.

In an atmosphere of trust, the adult shows faith, belief, and confidence in the child (van Manen, 1991b).The students found the scientists to be compassionate and understanding, so the students still felt good about themselves even if they felt they had made a mistake or lacked sufficient knowledge. To illustrate, Maree initially felt very vulnerable at the beginning of the programme as she felt she made errors and had inadequate subject knowledge. The tension between what she knows and what she could know does not dissipate immediately but over time as she realised a trusting relationship had built between her and the scientists. Trust reduces uncertainty and anxiety, so students can focus on learning (Tschannen-Moran & Hoy, 2000).

Sincerity is about being honest and genuine and involves emotions that are truly deeply felt. The students perceived the scientists to be genuinely interested in them as individuals, not as a class of students. They acknowledged the scientists cared enough about them to willingly give of their personal time and themselves. The students found the scientists were friendly, fun to be with, and had a great sense of humour. Furthermore, the scientists were prepared to interact with the students in more than a formal student-teacher relationship by willingly joining in their games such as cricket. In addition, the scientists were very receptive to involving the students' families and the local community in the programme. These personal relationships were very important to the students as they, "tend to experience instructional relations as personal relations. It matters to them how they matter to their teachers" (van Manen, 1999, p. 23).

Equity refers to "fairness and social justice" (Ministry of Education, 2007, p. 10) and involves treating others in a fair, evenhanded manner so they all have an equal opportunity to succeed. All the participating students had an equal opportunity to participate within the partner and small group organisational format as opposed to the traditional demonstration approach they had previously experienced in science. Moreover, the students appreciated the fair and respectful manner the scientists treated them, for instance explaining scientific concepts and ideas in a way the students could understand.

The ethic of caring as inherent in the concept of manaakitanga is the foundation of successful teaching and learning (Bishop et al., 2009), and was very evident in the Chemistry Outreach programme. These "caring encounters are, by their very nature, variable, situated and unique " (Goldstein, 1998, p. 246). The students felt the scientists cared about them as individuals and as a whole person, not just about student achievement. The scientists created a climate where the students felt cared for, accepted and respected, and therefore comfortable and relaxed in the learning environment. This resulted in the students feeling safe and secure enough to challenge themselves with new learning, in other words, authentic risk taking and learning could take place.

6.4 Tangata whenuatanga

Tangata whenuatanga refers to "place-based, socio-cultural awareness and knowledge" (Ministry of Education, 2011, p. 16). It involves using the physical surroundings, the whenua or land, as well as the associated cultural, social and historic traditions that connect the people who live in this environment as part of the curriculum. This pedagogical approach views the child in a holistic and mutlilayered way acknowledging the influences embedded within the child's family, school, community, and environment.

The community studied here has a strong affinity with the land. These connections relate to historic, economic, recreational and social aspects. Many residents have farming in their background with their parents and previous generations having farmed the land, although not necessarily in this particular area. There is a respect of what had happened in previous generations, an awareness of what their parents and grandparents had done, where they had lived and how they had farmed (CM12; CM8). There is an awareness that if managed sustainably, the land can produce a living either as sheep and beef farming as at present and/or possibly a reintroduction of mineral mining as took place in this area in the past (P14; CM3).

Farming related activities such as sheepdog trials,[21] gymkanas,[22] and rodeos provide opportunities for social connectedness within families and between members of the community. Rural events such as field days[23], and Agricultural and Pastoral Shows[24] are treated as family outings and the children would take time off school to attend them with their family. Often these activities engender connections between generations (P10;

[21] Sheepdog trials are a competitive sport where sheepdogs herd sheep as directed by the dog handler/shepherd around a predetermined course with obstacles.
[22]A gymkana is a competitive event for horses, ponies and their riders, usually involving a course over fences or obstacles.
[23] Field days involve static and working demonstrations of farm machinery and general equipment.
[24] Agricultural and Pastoral Shows, commonly referred to as A and P shows involve the exhibiting and judging of livestock, farm produce, and farm machinery stalls.

CM5). For instance, many families in this area are very much into the annual sport of duckshooting. The children are involved as well and their elders often took the opportunity to instill in the children the traditions of duckshooting. This proves to be a shared experience with the older generations teaching the younger generation many of the duckshooting rituals, such as making a mai-mai[25], rising before sunrise on duck shooting morning, how to stalk ducks on a pond, and wearing camouflage clothing and face paint.

The school grounds provide community connections through history and social events. The community takes a great pride in their history, and many of the well-established trees in the school grounds celebrate aspects of this settlement's history. Plaques beside these trees acknowledge respected community members, past school principals, school centennials, celebrations of the discovery of gold in the district, and various service clubs such as the Lone Cubs. The school has substantial grounds dominated by deciduous trees and over 300 daffodils the students planted along the school boundary fences. The grounds look very picturesque, especially in spring and autumn, and passing tourists often take photos of the grounds. The school grounds, including the tennis court, netball court, rugby field, and swimming pool, are well used by the community for sports fixtures, community and family picnics, and children's birthday parties after school hours.

The children are aware of the importance of land in their lives. They see farming in action daily, and are aware that land produces an income for their family to live on. As well as helping with aspects of farming life, the children use the land as a playground for recreational activities. Many of the children have horses and child-sized farm motorbikes to use on the farm, and are involved in rabbit shooting on the farm and fishing in the local river and streams on their farms.

The students demonstrate strong connections with the land at school as well. There is a school vegetable garden where the children tend their individual garden plots. The vegetables are used for shared school lunches and to take home to their families. Native

[25] Mai-mai is a camoflagued and concealed duck shooting position.

grasses planted around the new school sign were donated to the school in recognition of the children's efforts in recycling paper. School pet days are an annual tradition, and playground tree climbing to great heights was a daily pastime for most of the children.

Within the context of the Chemistry Outreach programme, tangata whenuatanga refers to the provision of learning opportunities that incorporate the "place-based, socio-cultural awareness and knowledge" (Ministry of Education, 2011, p. 16) of the learners' lifeworld. This is evidenced in the way the scientists acknowledged the students' culture as rural, and provided learning contexts that affirmed the culture of the learners and their family/community. The Chemistry Outreach programme involved the use of the local rural environment and emphasized practical, authentic, meaningful, and relevant experiences. Phase two of the programme entailed a hands-on approach with the students involved in the preparation, planning, and carrying out of the activities. The focus was on soil and water testing, in particular pH testing, as the students had assisted with water testing at the school community pool and had observed soil testing on the farm. They were aware of the importance of testing pool water for safety reasons, and the testing of soil on their parents' farms before fertiliser application. However, their understanding of what the process entailed and why was limited. The students brought and tested water samples from ponds, rivers, streams and troughs on their farms, and soil samples from a variety of farm paddocks. Phase three involved the students using these skills to plan, conduct and evaluate their own scientific investigations within the community. The intention was for the students to use their newly acquired skills and knowledge in a meaningful, authentic, student-driven context that would have relevance for them, their families, and the community. Therefore, the students' scientific investigations were located on the local farms with the students having control over deciding which farms and whereabouts on these farms to gather the data.

The school end of year concert is regarded as a community event and is attended by young and old alike from the community. The students presented a summary of their investigation process, including the analysis of the data at the end of term community assembly (see Penrice & Sexton, 2012, 2013). It is of note that farmers at the community presentation pointed out the significance both nationally and globally of the students' investigation topics of water and soil nitrates. They acknowledged the students' evaluations had added to their own knowledge in these areas. In this respect, the students participated as active contributing citizens for the betterment of their community (Sobel, 2004).

Effective teaching and learning occurs when there is an alignment between educational experiences and the students' personal experiences within their family or community (Bishop & Glynn, 2000). Personal experiences are often referred to as students' "worldview" (Bell, 2011, p. 42), or "funds of knowledge" (Cowie et al., 2011, p. 347). If students are given the opportunity to bring these experiences into the classroom-learning context, they have the potential to yield rich, useful, and transferable cultural knowledge (Calabrese Barton, 1998). It is vital "that students have access to science ideas that are local and relevant if they are to appreciate how science impacts on *their* lives" (Cowie et al., 2011, p. 362, original italics). The use of the students' natural and socio-cultural environment as an authentic learning context, often referred to as place-based education (Sobel, 2004), centres on the local community and environment, and focuses on hands-on real-world local learning experiences. The use of authentic, meaningful, relevant contexts from students' local environment helps to develop stronger links between students, their learning, and their community.

6.5 Wānanga

Wānanga is about "robust dialogue'' (Ministry of Education, 2011, p. 7), which involves the "rich and dynamic sharing of knowledge. With this exchange of views ideas are given life and spirit through dialogue, debate and careful consideration in order to reshape and accommodate new knowledge" (Bishop et al., 2003, p. 96).

The community values the discursive sharing of ideas and this is particularly evident in relation to farming, with the participation in farm discussion groups, the attendance of farming seminars, and informal farming discussions in one-to-one or small group contexts. This gives the farmers the opportunity to reflect on their own practices, assess and evaluate new ideas and adapt those which were applicable to their farming situation (CM6; P9). Events that are likely to affect the community as a whole, such as the introduction of a cycle trail as part of the national cycle trail network, farm water schemes, and the possible reintroduction of mining in the area, are discussed mainly in informal contexts such as one-to-one or small groups as opposed to community public meetings (CM4; CM3).

Group dialogue is also part of the school culture. Students are encouraged to give feedback which acknowledges the positive aspects of an individual's work and then give constructive feed forward to help the student improve their work. Group reflection ensures students' attempts and ideas are valued, and assists in the co-construction of further improvements or adaptations.

Within the context of the Chemistry Outreach programme, wānanga refers to the ways the scientists engaged in effective teaching interactions that value the students as rural learners. These interactions include "discursive teaching practices and student-student learning interactions" (Savage, Hindle, Meyer, Hynds, Penetito & Sleeter, 2011, p. 188), and relate to aspects of "communication, problem solving, and innovation" (Ministry of Education, 2011, p. 16).

A student-centred discursive environment was established early on in the Chemistry Outreach programme though small group and partner organizational formats. This facilitated student-to-student/s interaction and enabled scientific knowledge to be talked into being (Gallas, 1995; Lemke, 1990; Siry et al., 2012). Discourse was student initiated as opposed to the teacher-dominated discourse common among transmissive pedagogies. By students taking ownership of the discourse genuine power sharing developed between the students and scientists within the learning environment (Hipkins et al., 2002). This format valued and prioritized students' voices as they negotiated and communicated their shared understandings. The co-construction of knowledge was evident in the videos of the scientific experiments towards the end of the programme where the students collaboratively constructed meaning within the social setting. This echoes the perspective advocated by Vygotsky (1981) that the sharing and refining of ideas within the social context precedes the internalization of knowledge by the individual.

As the Chemistry Outreach programme progressed from a structured to an open inquiry format, the learning became integrated with practice through a problem solving approach. A scientific problem involves a situation that is new to the students and where "thinking is involved in generating, considering, and evaluating multiple solutions" (Jadrich & Bruxvoort, 2011, p. 117). The learning experience centred on the students as they initiated and designed innovative scientific investigations applicable to their community's environment. These investigations were original, and therefore innovative, as neither the scientists nor the farming community had previously explored these aspects. Therefore the students were engaged in more than "problem doing" (Jadrich & Bruxvoort, 2011, p. 117) where the adults, or the textbooks, already know the answers, but true problem solving requiring considerable thinking on the part of the students. During the problem solving process the students were actively involved in the discursive sharing of ideas, using prior knowledge, finding out relevant knowledge, and constructing new meanings and understandings (Bishop & Glynn, 2000; Jadrich & Bruxvoort, 2011).

The Chemistry Outreach programme focused on real life problems from the students' world, and therefore is significant to the lives of the students and their community. The problem solving process involved the students in the discursive sharing and refining of ideas, similar to the way their parents gained access to new or adapted farming ideas.

6.6 Rural Primary School Science

The literature on culturally responsive pedagogy often refers to marginalized or minority school populations whose culture is not the dominant Eurocentric "middle and high socioeconomic status (Aceves & Orosco, 2014, p. 7) culture prevalent in mainstream schooling. In the New Zealand context there is considerable research on culturally responsive teaching within the context of Māori education (Bishop et al., 2009; Macfarlane, 2004) and Pasifika education (Samu, 2006). Often these populations are a minority group within a larger school population and this pedagogy is utilized in order to address the diversity within the school, and to address underachievement concerns.

With respect to this study, the culture is very homogenous, in that it is the dominant culture for all the students of the school. To the best of this researcher's knowledge, culturally responsive pedagogy has not been considered within the context of a predominantly Eurocentric rural culture. Culturally responsive pedagogy for this rural primary school involves the lives of the students having a significant influence on the science programme and teaching-learning strategies. As such, it is very situated and unique to this specific rural school where the rural students are placed at the centre of the learning, and can learn as rural students. The following core aspects of relationships, students' lifeworld, and learning have been identified as important within this particular rural culture.

Relationships are fundamental to the learning and teaching process (Giles et al., 2012; Palmer, 1998; Tate, 2007). The acknowledgement and respect of each other's cultures helps to develop positive working relationships between the teacher and the students, and strong connections between the school and the students' families and community. It is through relationships a supportive and caring learning environment incorporating respect and a sense of belonging and the values of caring, integrity, trust, sincerity and equity is built and nurtured. Such an environment can engender a positive, relaxed learning atmosphere where students feel secure and confident in focusing on the learning process, in particular the understanding of scientific concepts and ideas, with mistakes, misconceptions, and lack of knowledge accepted as part of the learning process.

Aligning the students' lifeworld within their family or community and educational experiences results in effective learning and teaching (Bishop & Glynn, 2000; Cowie et al., 2011). The students' culture matters to them, and the incorporation of "place-based, socio-cultural awareness and knowledge" (Ministry of Education, 2011, p. 16) within the curriculum enables students to bring 'who they are' to the learning environment. This adds relevancy and authenticity to the learning for the students, and serves to forge strong links between home and school.

Learning science is a social activity (Gopnik, 2012; Jadrich & Bruxvoort, 2011). When students enjoy positive, caring, inclusive relationships, and feel it is acceptable to bring 'who they are' into the learning situation, they are better able to actively participate in collaboratively co-constructing knowledge. Reciprocal teaching and learning positionings, which result in power sharing relationships between adults and students enhance this environment of shared sense making and knowledge construction. Furthermore, student ownership and self-direction over their own learning is encouraged through the collaborative discursive sharing of ideas within open-ended student-directed problem solving situations.

This study recognizes rural culture as a culture in its own right, and the students as rural learners. The rural culture is incorporated within the teaching and learning programme, not simply as a context, but as an integral component of a culturally responsive pedagogy for this specific rural primary school's science programme. The Chemistry Outreach programme studied here was more than a place-based education programme with hands-on real-world investigations within the local community and environment. Furthermore, this programme was more than an externally provided science programme with the science community supplying the expertise, resources, and university students as role models. The analysis has revealed the importance of an awareness and understanding of the students' school, family and community culture and how this impacts on the students' attitudes and learning. Knowledge of what the students, their parents and community do, think, and how they learn can play an important role in establishing strong connections between the students and their lives within the school and out of school. Dr Warren, the Chemistry Outreach facilitator, and I worked together to ensure the cultural fit of the programme to the students' culture as best we could. In this instance, the students' culture was not just related to the rural location, but entailed the specific ways the students, their parents, and the community engaged in relation to thinking, doing, and learning. Consequently, the programme provided a meaningful, relevant, authentic learning experience with strong connections between the students and their specific rural culture. As a result, the strong cultural fit of the programme to the students' culture facilitated the students' positive experience of the programme.

CHAPTER SEVEN
CONCLUSIONS

7.0 Introduction

This study has provided a rich insight into the lifeworld of nine rural primary school science students as they experienced a year-long Chemistry Outreach programme. The programme involved a partnership between the school and the University of Otago Chemistry Department, whereby the facilitator, Dr Dave Warren and selected postgraduate science students worked with the students and myself, as teacher, on a regular basis throughout the year culminating in student-directed scientific investigations relevant to the rural community the students live in.

The results have revealed the individual journeys the students took, and in the process, have exposed the multifaceted influences that affected their thinking and learning in science. Throughout the study, the voices of these students can be clearly heard as they discuss and talk about science, participate in science activities, and develop their scientific understandings.

7.1 Recapitulation of purpose and findings

The purpose of this study was to examine the influence of the Chemistry Outreach programme on nine rural primary school students' attitudes towards school science, engagement with school science, use of scientific skills, and use of scientific language. Each concept was examined separately, although it is acknowledged that although these concepts and the resulting sub-themes are categorised as four separate entities, in reality, the parameters between them often overlap. Comparisons of the data gathered before the Chemistry Outreach programme started, as well as during and at the end of the programme were used to investigate the influence of the programme on the students.

The study is underpinned by the phenomenological stance that views learning as involving the heart (attitude towards science), hand (engagement with science), and head (use of scientific skills and language) (Henriksson & Friesen, 2012). Apart from the attitudinal data, a two-tiered approach was used in data gathering and analysis which incorporated both the students' individual and social responses. The findings are presented in relation to the main research question: What are rural primary school students' experiences of a Chemistry Outreach programme, as well as the subquestions: How does the student's experiences with a Chemistry Outreach programme change their attitudes towards science? How does the student's experiences with a Chemistry Outreach programme change their engagement with science and their intention to continue with school science? How does the student's experiences with a Chemistry Outreach programme change their use of scientific skills and language? How does the Chemistry Outreach programme respond to the students' rural context and upbringing? As this research takes place within the micro-culture of a very small rural school, and is influenced by the macro-culture of Aotearoa New Zealand, the findings are then discussed in relation to this school's unique culture and the cultural responsive pedagogy outlined in *Tātaiako* (Ministry of Education, 2011).

7.1.1 Attitude

For the purposes of this study, attitude was defined as the students' affective responses to the Chemistry Outreach programme. Data were gathered from student focus group interviews, student reflective writing, and science book cover designs. This study established the students' attitudes towards science before the programme started and then tracked any attitudinal changes that occurred over time including when these changes occurred. The findings revealed three very different pathways undertaken by the students with regard to their favourable response towards the Chemistry Outreach programme. Initially, only three students spoke positively of the Chemistry Outreach programme and they retained this positivity throughout the duration of the programme. Another three students were positive but had some reservations, whilst a further group of three was initially negative about the programme. The timing of the change of attitude occurred over a period of five visits starting with the second visit so that by the beginning of phase 2, after 6 visits by the scientists, all the participating students spoke of a positive emotional connection with the Outreach Science programme. This attitude continued throughout the remainder of the programme. These findings confirm the research literature which recognizes attitude as being predisposed to change over time (Ajzen, 2001; Wilson et al., 2000), and as an individualised response involving the student's innermost private thoughts about how they experienced the learning context (Nuthall, 2007; van Manen, 1991b). Of interest is the timing of the change in attitude for those students who did not initially have positive attitudes towards the science programme. The change towards a more positive attitude towards science coincided with more active hands-on participation by the students within a guided and open inquiry programme. These findings are consistent with previous research which highlights practical hands-on science activities as one of the influences in promoting positive attitudes towards science (Logan & Skamp, 2012; Swarat et al., 2012)

It was through speaking and writing about their involvement with the Chemistry Outreach programme, underlying influences, other than practical hands-on activities, were revealed that could account for the shifts the students experienced towards more positive attitudes in relation to school science. These influences related to first, the emotional connectedness with the subject matter, that is the Chemistry Outreach programme, and second, the relational connectedness with the people, that is the scientists. In other words, the students' favourable responses to the Chemistry Outreach programme were a direct result of the scientists as teachers, and the learning environment they created.

The students found the Chemistry Outreach scientists were passionate about science and were keen to pass this passion onto the students by making science enjoyable and fun. They embodied science, as living examples of scientists doing science, living science, and being scientists, and as a result were great role models of 'real' scientists for the students. These results support the literature that found the enthusiasm of the science teacher helps students develop positive attiudes towards science (Abrahams, 2009; Darby, 2005; Forbes, 2014; Palmer, 2007).

The students spoke at length about the personal relationships the scientists had formed with them as indivduals, not as simply a class of science students. This was very important to the students as, “students tend to experience instructional relations as personal relations. It matters to them how they matter to their teachers” (van Manen, 1999, p. 23). The scientists demonstrated they were supportive of the students’ learning by taking the time to build strong relationships with students (George, 2000, 2006; Whitten et al., 2003). This was a reciprocal relationship as the students felt they had got to know the scientists as people. This strong personal connection with the scientists helped the students to make positive conections with the subject matter the scientists presented. Relationships are a crucial part of the education experience (Gibbs, 2006; Giles et al., 2012), and positive student-teacher relationships are a powerful influence on student attitude and as a consequence student learning (Cornelius-White, 2007; Frymier & Houser, 2000; Hattie, 2012; Palmer, 2007). One anomaly did occur with one student considering one of the scientists as his friend. This is contrary to the research findings that indicate students prefer teachers to be friendly with them, but not to become their friends (Henriksson, 2008).

The students were aware of the scientists’ concern about breaking down any potential barriers to learning, by using trust and humour, and accepting students’ errors as part of the learning process. A climate of trust enables students to relax and to feel secure and confortable with the scientists and therefore more receptive to learning with the scientists (Hattie, 2012; Nuthall, 2007; van Manen, 1991b). The use of humour helped to break down down any feelings of power inbalances between the children and the ‘expert’ adults (Olsson et al., 2002). The climate of trust and humour meant the students could focus more on enjoying and learning science as opposed to feeling threatened or embarrassed by a lack of knowledge or understanding (Martin et al., 2003; Forbes, 2014; Palmer 2007). As a result, the students considered the scientists were interested in the students’ well-being by providing a friendly, relaxed, safe, and supportive learning environment conducive to developing positive attitudes towards science (den Brok, Fisher & Scott, 2005; Whitten et al., 2001).

The aforementioned underlying factors of influence contributed to the students developing a relational connectedness with the scientists and an emotional connectedness with the programme which helped in establishing positive attitudes towards science. These results highlight effective pedagogy as being more than just content knowledge and pedagogical strategies, but also about people, in this case, the students and the scientists, and how they relate to each other (Palmer, 1998; van Manen, 1991b). They add to the growing body of research literature that has shown that positive student-teacher relationships and supportive learning environments are powerful influences on students' attitudes and learning (Cowie et al., 2011; Darby, 2005; Logan & Skamp, 2012; Osborne et al., 2003; Palmer, 2007; van Manen, 1991b). Furthermore, the findings extend this literature by giving practical examples from the students' perspective of ways teachers can enhance students' relational and emotional conectedness with science.

7.1.2 Engagement

Engagement in this study is confined to the behavioural aspects which include the students' participation, persistence, effort and/or attention in relation to the subject matter (Capella et al., 2013; Fredricks et al., 2004). Data was gathered through videos of students engaged in scientific experiments, focus group interviews, and the students' reflective writing. The focus was on first, the students' social response to science which investigated the students' task engagement within the context of group science activities, and second, the students' individual responses which revealed their short-term engagement with the Chemistry Outreach programme as well as their perceptions of long-term engagement with school science as evidenced in their predictions of whether they would continue with secondary school science education once it was an optional subject.

The first small group scientific experiment revealed two examples where peer relationships affected students' engagement with science. First, the group used their power to coerce selected group members to conform to the dominant norms of the group (Foucault, 1977). This normalizing effect reduced the individual student's opportunity to engage with the science, for instance Lisa's and to a lesser extent Kelly's control of Shane's actions, and Ken and Maree's exclusion of Peter's participation. Second, individuals within a group setting may feel a need to conform in an effort to maintain social harmony as was instanced in Peter's reduced participation in the first experiment, compared to his greater engagement in the second experiment when he worked with his self-selected group. These findings support literature that claims peer relationships and task engagement are interrelated especially in small group settings (Gristy, 2012; Hattie, 2012; Nuthall, 2007).

All the participating students demonstrated increased task engagement during the second science group experiment which occurred towards the end of the programme. The students consistently displayed more on-task behaviours, showed considerable effort in executing the task, demonstrated ongoing attention throughout the period of the task as well as persistence in the task completion. This improvement could be attributed to the format of the Chemistry Outreach programme which consisted of self-selected partner and group work, and the expectation that students would work together in a collaborative way and focus on the task on hand.

As the students spoke about their experiences with the Chemistry Outreach programme underlying factors of the scientists' expertise, the authenticity of the programme, and the opportunity to actively participate in the science activities were revealed that could explain the students' increased engagement in school science. The students valued the scientists' expertise, crediting their own developing knowledge and engagement with science to the manner in which the scientists used their expertise to clearly explain and clarify scientific ideas, and were prepared to include students' questions and discussions within the programme. These findings are consistent with other research studies which have found an increase in student engagement as the result of access to scientists' expertise (Bolstad & Bull, 2013; Forbes, 2014).

The Chemistry Outreach programme was perceived to be more authentic than what these students had previously experienced.The students felt they were regarded as equals with the scientists especially as they were undertaking investigations the scientists had not done before. Student ownership and control of learning experienced through self-initiated scientific investigations and the opportunity to work collaboratively are conducive to increasing student engagement (Chin & Osborne, 2008; Forbes, 2014).

Finally, the students preferred the practical hands-on approach taken by the Chemistry Outreach programme as it gave them the opportunity to be actively involved in the science investigation, participate in the data gathering procedures, and have the agency to repeat or change aspects of the experiment to double check findings and/or predictions. Practical hands-on investigative science is the preferred pedagogical approach in science learning (Abrahams, 2009; Barmby et al., 2008; Skamp, 2007; Swarat et al., 2012), resulting in students being engaged during science activities and wanting to do more science at school (Kerr & Murphy, 2012).

Although the students spoke about and demonstrated their increasing engagement with the Chemistry Outreach programme, this proved not to be a reliable predictor of their perceptions of long-term engagement with school science. Four students indicated they definitely were going to take secondary school science once it was no longer compulsory, and two students were on the way to being decided. However, although the three students who remained undecided indicated they were interested in science, they wanted to be free should other options become available. These three students were aged ten and older, the age at which Murphy and Beggs (2005) found students lose interest in science. This highlights an urgency to provide science programme in particular to students younger than ten that not only engages them but also demonstrates the relevancy to their own lives and therefore the importance of post compulsory secondary school science even if they are not intending to pursue a science orientated career.

7.1.3 Scientific skills

In the context of this study scientific skills refer to scientific investigation skills and encompass what scientists do and what they think about when they are engaged in scientific endeavours (Ambross et al., 2014; Feasey, 2012). Data on the students' perceived ability in scientific skills were sourced from the students' self-reports of their ability in scientific skills. Information on the students' procedural and meaning-making skills within the context of a small group was obtained from videos of the students engaged in scientific experiments.

All the participating students' self-reports demonstrated an increasing awareness and understanding of the procedural skills used in scientific investigations, particularly in the area of data collection and data handling. These were skills which were specifically taught by the Chemistry Outreach scientists and practiced within meaningful contexts as part of the students' self-directed scientific investigations. Furthermore, all the participating students demonstrated an increased ability and confidence in using procedural and meaning-making skills within small group science experiments. This can be attributed to the format of the Chemistry Outreach programme which incorporated the development of scientific skills with the construction of scientific knowledge within meaningful hands-on, inquiry-based investigations. The results of this study are consistent with the results of similar recent studies that found scientific skills improved as a result of inquiry based programmes (Anderson, 2002; Simsek & Kabapinar, 2010; Yager & Akcay, 2010), hands-on inquiry approach (Bilgin, 2006; Dökme & Aydinli, 2009; Ergül et al., 2011; Turpin & Cage, 2004), and the opportunity to practise skills (Wu & Hsieh, 2006).

Group work was the predominant organisational format of the Chemistry Outreach programme. However, individual student's use of scientific skills can be affected by group socio-organisational influences (Southerland et al., 2005; Varelas et al., 2007). The results of this study support the literature that views interconnections between cognitive behaviours and social relationships within the group can affect the degree of an individual's participation in the use of scientific skills (Anderson et al., 2008; Southerland et al., 2005). But this study's findings differ from the view that high academic students control group discourse and their ideas dominate the discussion (Bianchini, 1997; Moje et al., 2011). The examples of Peter, a high achieving student, dominated by others in his first group activity, and John, dominating his intellectual superiors, highlight the fact that the influence of academic status within a group context may be more complex than indicated by these researchers.

Over the duration of the programme, there was evidence of more inclusive, cooperative group skills in relation to role negotiation, working relationships, and the acceptance of others' contributions thereby creating a positive climate for students to readily participate in scientific skills. These learning aspects were the norm for the community (see 6.1 and 6.2). It needs to be acknowledged these students had experienced transmissive, demonstration type scientific lessons prior to the Chemistry Outreach programme. Therefore, at the beginning of the programme, the students treated new scientific experiences in a very individualistic way as opposed to a cooperative group task. It was as the programme progressed that the home-community culture of cooperative working relationships started to be reflected in classroom practice. This can be attributed to the Chemistry Outreach programme where scientific activities were undertaken in group work and group teamwork skills were modeled and encouraged by the Chemistry Outreach team, in contrast to the students' prior experiences of demonstration type science sessions.

7.1.4 Scientific language

For the purposes of this study, scientific language refers to specialized vocabulary used to represent scientific ideas or concepts. Data was sourced from the students' use of scientific language in their oral recounts of school science experiences as well as within small group science experiments. The focus was not on students' competency with scientific vocabulary but the process they experienced in their attempts to discuss their observations of scientific phenomenon.

The students' recounts of their school science experiences showed all the participating students except for one demonstrated a transition from the use of everyday language to more scientific language over the duration of the Chemistry Outreach programme. This was attributed to first, the fact the students recounted experiences that had been discussed previously in class, and therefore could probably remember the type of language that was used in these discussions. Second, the transition to more scientific language could be as a result of the scientists' use of "double talk" (Brown & Spang, 2008, p. 708), a combination of everyday and scientific language. This confirms earlier research findings that indicate an increase in the students' use of scientific language when exposed to a hybrid form of language incorporating both everyday and scientific language (Brown & Spang, 2008; Roth, 2005b; Varelas et al., 2006).

The student who consistently used everyday language was still able to clearly articulate his developing understandings of a complex scientific phenomenon. This highlights the fact that student uptake of scientific language is more complex than code switching from one language to another. Rather, it is inextricably linked with the developing meaning and understanding of scientific ideas and concepts, and is an evolving or emerging process (Roth, 2005b). This process was further evidenced in the small group discourse. Shane's attempts, with varying success, to appropriately use dissolution vocabulary, even with the assistance from members of his group, demonstrates that the exposure and usage of scientific terms does not necessarily mean students understand and can use the scientific terminology correctly.

Student talk within the group settings provided the opportunity for the students to collaboratively co-construct meaning and talk their scientific knowledge into being (Gallas, 1995; Lemke, 1990; Siry et al., 2012). The findings revealed that as the students concentrated on co-constructing meaning, they used mainly everyday language, indicating they needed to use their way with words in order to own this way of talking and thinking about the world. Consequently, scientific language is not the only way to describe and explain science phenomenon (Brown & Ryoo, 2008; Roth, 2005b).

This study contributes to the debate regarding the importance of everyday and scientific language within the science classroom. The findings challenge Gee's (2004) claim that students' use of everyday language in scientific discussions is a liability. Instead, these results support the literature that understanding precedes the use of scientific language, as understanding does not exists in the scientific terms but the conceptual knowledge, and everyday language is the first step in the process of the emerging use of scientific language (Lemke, 1993; Roth, 2005b, Varelas et al., 2006; Wallace, 2004). Furthermore, these findings demonstrate that everyday language and scientific language need not be dichotomized but can be regarded as integral parts of the process of the communication in science (Ash, 2008; Brown & Spang, 2008, Rahm, 2003).

The Chemistry Outreach programme provided a supportive discursive learning environment where first the scientists modeled scientific language through their use of a hybrid mode of scientific and everyday language, scaffolding the students into the ways of scientific thinking and talking. Second, the use of everyday language was accepted as part of the process of evolving scientific language. Third, the students were given multiple opportunities to talk their scientific understandings and knowledge into being using first everyday and then scientific language (Gallas, 1995).

7.1.5 Rural primary school science

This research is situated in the micro-culture of a very small rural school within the macro-culture of Aotearoa New Zealand. Therefore the findings are discussed in relation to this school's (and community's) unique culture and the culturally responsive pedagogy as outlined in *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011). These competencies include ako (teaching and learning), whanaungatanga (relationships), manaakitanga (values), tangata whenuatanga (place-based, socio-cultural awareness and knowledge), and wānanga (communication, problem solving and innovation). Although these competencies are examined separately, in reality the parameters between them may overlap.

7.1.5.1 Ako

The concept of ako refers to both teaching and learning, and incorporates the principle of reciprocity where the teacher can be the learner, and the learner can be the teacher (Bell, 2011; Bishop & Berryman, 2009). Ako is embedded in the life of this community with adults regularly sharing farming knowledge with other adults, for instance, in farm discussion groups. The adults share knowledge with the children through sports coaching and farm skills, whilst the children share knowledge with the adults, such as aspects of their schooling. The school actively promotes the concept of tuakana-teina, a form of ako (Grazier & Meade, n/d), which involves the older or more expert students guiding the learning of the younger or less expert students.

The Chemistry Outreach programme's organization provided opportunities for adult-student/s, student-student/s, and student/s-adult knowledge sharing with an emphasis on small group and partner formats. This enabled knowledge-sharing and power-sharing in student-student/s and student-adult contexts within a cooperative learning context, highlighting the influence of the social context in the science learning process (Kelly & Crawford, 1997; Varelas et al., 2007; Vygotsky, 1981). As the programme progressed from a structured to an open inquiry format, the role of the scientists as teachers and students as learners became more interchangeable resulting in reciprocal collaborative learning situations. Tuakana-teina interactions were evident in the small group contexts towards the end of the programme and finally, students as teachers occurred during the students' sharing of their scientific investigations to the community. The culture of this rural community used a variety of knowledge sharing strategies amongst and between adults and children. These strategies were also used within the Chemistry Outreach programme, thereby helping to consolidate and increase the students' and community's knowledge.

7.1.5.2 Whanaungatanga

Whanaungatanga refers to the building of strong extended whānau family-like relationships where the group works towards a collective goal. There are strong connections between adults and children within this community, driven first by regular social contacts and second, the commitment to out of school competitive sports. The school has an extended whānau or family-like culture with an emphasis on working as a team, helping and supporting others, and celebrating successes and achievements within the class, school, or the public arena.

Within the context of the Chemistry Outreach programme, whanaungatanga refers to the building of respectful working relationships between the scientists and the students, and developing connections between the scientists, the students, and their families and community. This is evidenced by the respect for each other's culture, and the development of feelings of inclusiveness and belonging within the group through a variety of social interactions (see Appendix A: Chemistry Outreach programme).
The relational connections that developed over the duration of the programme between the scientists, the students, their parents and the community were built and nurtured over a period of time with a focus on the students' well-being and learning. They involved connections between scientists and students, parents and scientists, illustrating the inter-connected web of shared communal relationships (Palmer, 1998) focused on the collective responsibility for the students' learning (Giles et al., 2012).

7.1.5.3 Manaakitanga

Manaakitanga is about the ethic of caring for others and involves the values of integrity, trust, sincerity, and equity (Ministry of Education, 2011). The community displays manaakitanga towards the well-being of the community as a whole, with volunteer groups such as the local fire brigade, and individuals in the community as demonstrated in fundraising events for a local sick child. The parents of the school students know each other well and trust each other to care for their children. The school culture is influenced by the community-chosen values of respect and responsibility for oneself, others, and the environment. Manaakitanga is experienced by the children looking out for each others' welfare resulting in the students feeling a strong sense of being safe and protected.

Within the context of the Chemistry Outreach programme, manaakitanga refers to the ethic of caring for others, and involves providing a supportive learning environment that includes caring about the students' family, and cultural background, as well as their personal capabilities and their learning (Bishop et al., 2014; Ministry of Education, 2011). The students spoke at great length of the relational and emotional connectedness they considered had developed between them and the scientists. The values of integrity, trust, sincerity, and equity were modelled and encouraged by the scientists throughout the programme, and along with the ethic of caring, helped to create a learning climate where the students felt safe and comfortable with extending themselves in challenging new learning.

7.1.5.4 Tangata whenuatanga

Tangata whenuatanga refers to "place-based, socio-cultural awareness and knowledge" (Ministry of Education, 2011, p. 16). It includes the physical surroundings, the whenua or land, as well as associated historical, social and cultural traditions that connect the people who live within the environment. The community has a strong affinity to the land through historic, economic, recreational and social links. All farmers had farming in their family background, were aware of the importance of managing the land sustainably to ensure a continued income, and participated in social activities related to the land such as dog trials, field days and A and P shows. Connections with the land permeate school activities, for instance, individual garden plots for the students to grow vegetables, pet days, and regular tree climbing at playtime.

Within the context of the Chemistry Outreach programme, tangata whenuatanga was evident with the provision of learning experiences that affirmed the rural culture of the learners and their family/community. The students' presentation of their investigations to the community added to the local farmers' knowledge thereby enabling the students to be active contributing citizens for the betterment of their community (Sobel, 2004). The Chemistry Outreach programme aligned school educational experiences with the students' lifeworld using the students' natural and sociocultural environment as an authentic, meaningful, relevant learning context, thereby forging stronger connections between the students, their learning, and their community.

7.1.5.5 Wānanga

Wānanga refers to the social sharing of knowledge "though dialogue, debate and careful consideration" (Bishop et al., 2003, p. 96) in order to enhance or create new knowledge. The community engages in discursive sharing of knowledge through farm discussion groups and farming seminars. Group dialogue is also part of the school culture with students using constructive feedback/feedforward strategies in a collegial way to help co-construct adaptations or improvements to an individual's work or ideas.

Within the context of the Chemistry Outreach programme, wānanga refers to the ways the scientists engaged in effective teaching interactions that valued the students' rural culture. This included aspects of "communication, problem solving, and innovation" (Ministry of Education, 2011, p. 16), which were evident within the student-centred discursive environment and the problem solving approach inherent within the Chemistry Outreach programme.

The Chemistry Outreach programme focused on real life problems identified by the students from their world and therefore significant to the lives of the students and their community. The problem solving process involved the students in the discursive sharing of ideas, similar to the way their parents gained access to new or adapted farming ideas.

7.1.5.6 Concluding comments

This study was situated within a unique rural context, with an equally unique culture. This rural culture is recognized as a culture within its own right, and is incorporated into the science curriculum, not simply as a context for learning but as an integral component of the teaching and learning programme. Relationships, the students' lifeworld and learning were identified as core aspects of a culturally responsive pedagogy that places the rural students at the centre of the learning, and encourages these students to learn as rural students.

The establishment of positive student-teacher relationships grounded on the mutual acknowledgement and respect of each other's cultures as well as the formation of strong connections between school and the students' families and community provided the foundation for building and nurturing a supportive and caring learning environment. The opportunity for students to bring their lifeworld experiences into the learning interactions added relevancy and authenticity to the students' learning and helped to forge strong links between home and school. These relationships and learning environment enabled the students to actively participate in the collaborative construction of knowledge through the discursive sharing of ideas within student directed problem solving investigations relevant to the community the students lived in.

The analysis revealed the impact family and community culture has on these students' attitudes and learning. Establishing strong connections between these rural students and their lifeworld entails more than locating experiences within their rural location. Rather, it involves the knowledge and understanding of the specific ways the students, their parents and the community engage in thinking, doing, and learning, and incorporating these ways within the programme. The strong cultural fit of the Chemistry Outreach programme to the students' rural culture was influential in students' positive experience of the programme.

7.2 Limitations of research

I should stress that this present study has been primarily concerned with nine rural primary school students and the influence the Chemistry Outreach programme had on their attitude towards school science, engagement with school science, and use of scientific skills and language. I should make it clear that I wished to focus in-depth on these specific aspects of the students' science experience. Therefore, although there are other aspects pertaining to science education, such as student achievement, they are not included within the scope of this study. This narrowing of focus may have given the impression that these areas were of more importance that others, however, this was certainly not my intention. These other aspects, for instance student achievement could certainly provide another perspective into the influence of the Chemistry Outreach programme. Background information on rural schools' student achievement in relation to non-rural schools' performance is not readily accessible through the PISA and TIMMS results but could be easily accessed through the NEMP results.

Methodologically, it could be argued as to whether nine participants are sufficient to allow valid conclusions to be reached. As I used an interpretive approach for the data analysis, I feel what is lacking in numbers is certainly made up in the in-depth results. This was aided by the two-tier approach to analysing and reporting the data, which involved the students' individual and collective, or social, responses. I feel that this revealed more of the complexity, and ever-changing nature of the learning process experienced by the students. These nine students did reveal a range of affective, behavioural, and cognitive dispositions thereby giving me the confidence that this study encapsulated some of the variety of students' responses to a school science programme.

In light of these comments, I would caution that my findings should not be read as evidence for all primary school students, as this research was firmly located within the context of a very small two teacher rural school. Furthermore, the findings of this study can not be considered as representative of all very small two teacher rural schools. This particular community was homogeneous in the respect that all students were from a rural sheep and beef farming background. Therefore the findings can not be generalized to other very small rural schools due to the diversity in the culture and background of these schools in New Zealand.

7.3 Problems encountered and lessons learned

The following details problems during the data collection and the research design stage I encountered during the study. The effects of these problems are discussed and there are indications of my attempts to resolve them. I then reflect on how this study could have been improved.

7.3.1 Problems encountered

Initially I had intended to use a mixed methods approach where quantitative data would inform the predominantly qualitative research data, even though I was aware that the integration of both quantitative and qualitative data could be problematic. As Bryman (2007) succinctly states "the key issue is whether in a mixed methods project, the end product is more than the sum of the individual quantitative and qualitative parts." (p. 8). I had proposed to use a National Educational Monitoring Project (NEMP) science attitudinal survey as a way to compare these students' results with the national data on attitude to science in primary schools, thereby adding to the more comprehensive picture of attitude gained through the interviews. After much deliberation, I decided that using this type of quantitative data would not enrich the data already gathered. Furthermore, it was not possible to compare the results with the national data as this was focused on Year 4 and Year 8 children whereas the participants in this research ranged from Year 4 to Year 6. Although I administered the survey at the beginning and the end of the research, the data was not used in the data analysis. I found it was more productive to use the qualitative data from the focus group interviews, reflective writing, and science book covers as it indicated nuances and possible explanations for the changes in attitude over time.

Working as a full-time teaching principal limited my available time for data transcribing. This problem was overcome by hiring a professional transcriber. I then personally checked all the transciptions for accuracy against the video and audio-tapes. This enabled more efficient use of my time and efforts.

The original research design contained two main research questions, the first examining the influence of the Chemistry Outreach programme on the students, and the second question exploring the views of science and science education from the students, their parents, and the immediate rural community members. As the research progressed, it became obvious that including both research questions would generate too much information for one study, thereby resulting in a superficial rather than an in-depth study.

Consequently, the decision was made to focus solely on the first question relating to the students and the science programme. This was a great disappointment for me because the original intention was to provide a complete picture of science and science education from a rural perspective of those who are directly and indirectly involved. As part of the data gathered for the second research question entailed the adults' descriptions of the community, this information was used in Chapter Six in relation to aspects of this community's rural culture.

7.3.2 Lessons learned

Taking into consideration the limitations of this present study, problems encountered and reflecting back over the past four years, there are areas where this study could have been improved. Three aspects of the research design could have had the potential to affect the quality of the findings.

The first aspect was the decision to use the jelly crystal activity and the magnesium tape experiment as group science activities. Suitable reasons were given for this decision at the time, namely for comparison purposes to establish changes over time. However, in actual practice, these activities proved to be time consuming, and the students' focus was mainly in the procedural aspects of completing the task. Furthermore, the jelly crystal activity gave the students the opportunity to plan and conduct an investigation whereas the magnesium tape activity had written step-by-step instructions. This made comparisons of the students' participation difficult. In retrospect, a better choice could have been to record the students' discussions amongst themselves during the planning, designing, and carrying out of their own scientific investigations. This would have afforded an insight into more aspects of the students' behavioural and cognitive perspectives whilst they were involved in an authentic, self-directed scientific investigation.

The second research design aspect involved the data gathering, which focused on the focus group interviews with supporting information from the videos of the students engaged in science activities. Although these videos were lengthy and time consuming to transcribe they were valuable as they offered nuances such as power relations, and role negotiations which were not apparent in the interview context. In hindsight, the most valuable information came from these videos, when the students were engaged in talking and doing science within a social context.

The third research design aspect under review was the timing of the third focus group interview which took place in Term 1 the following year, after the six-week summer holidays. In retrospect, it would have been beneficial to have another focus group interview a few weeks after the end of the programme which involved the presentation of the students' investigations to the community. This would have afforded more of an insight into the students' responses immediately after the completion of the programme, and then this could be compared with a further interview 10 weeks later to establish the longer lasting effects of the programme.

7.4 Implications for future research

This study has shown how the Chemistry Outreach programme influenced positively on these students' engagement with and attitude towards school science. However, this did not equate to an accurate indication of long-term engagement with school science, that is to say choosing to participate in secondary school science once it became an optional subject. As it is not possible to generalise from this very small sample, the exploration of attitudes and engagement at primary school level as predictors of long-term engagement with school science could be a possible area for future research. This is of importance as research has indicated that students can lose interest in science after the age of ten (Murphy & Beggs, 2005), and as rural students are surrounded by science, they need to see the relevancy of school science for their own lives even if they do not pursue a science career.

To the best of my knowledge, this research is the first research study to conduct a qualitative investigation of the influence of a science initiative programme specifically on

New Zealand rural primary school students. The analysis of the data recognised the bicultural foundations of Aoteoroa New Zealand and used a culturally responsive pedagogical framework adapted from *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011) to further discuss the findings in relation to the specific Eurocentric middle class socioeconomic rural culture of the school and community. The study identified successful teaching and learning strategies applicable to this specific rural school and its culture, thereby contributing to an understanding of the vital role rural culture plays in these students' science learning. One of the limitations (see 7.2) of this research is the lack of generalizability. Many rural schools' cultures are dominated by one or more agricultural influences for example, grapes, dairying, forestry, and/or non-agricultural influences, for instance, tourism and fishing. It would prove valuable to investigate whether the findings emerging from this research study are indicative of this specific rural primary school only, or can be applicable to a wider range of rural schools.

7.5 Recommendations

There are currently calls to establish teacher 'science champions' in each school, or across schools, to lead science professional development and facilitate the development of school science programmes in an effort to improve teacher confidence in delivering programmes that incorporate a sense of "scientific enquiry and scientific enthusiasm to young minds" (Gluckman, 2011, p. 5). This can prove difficult for very small rural primary schools, first, because they are often geographically isolated, second, they have a limited budget, and third, these schools have very limited number of teaching staff. Furthermore, it is pertinent to note that New Zealand primary school teachers are generalists who teach all subject areas of the curriculum. Therefore, very small rural schools do not have specialist science teachers as is possible in some larger urban schools. Many rural school teachers could feel inadequate teaching primary school science due to their perceived limited scientific knowledge base and skills (Bull et al., 2010; Cooper et al., 2011; Cowie et al., 2011). As a result they could lack confidence in encouraging students' in-depth discussions and questions in case they are unable to locate information or resources to help their students construct scientific understandings.

The findings from this research indicate that the Chemistry Outreach programme has the potential to serve as a science champion facilitator for very small rural schools. This programme can provide schools with scientific expertise, up to date scientific knowledge and access to resources for both the students and the teachers, as well as role models for the children. The findings in Chapter Four demonstrated that it was not only the scientists' knowledge and skills which were regarded as important; relational connectedness was also viewed as being very valuable. The multiple engagement format over time used by the Chemistry Outreach programme enabled the development of these interpersonal relationships between the scientists, the students and the teacher. Given that very small rural schools have limited budgets and personnel to commit to interschool teacher professional development and student visits to science learning centres, there could be a case for the science community in partnership with the school delivering part of the school's science programme within the students' own community.

7.6 Contributions to research

As well as indicating some possible areas for future research, my study has made three particular contributions to the literature regarding primary school science. These include the investigation of science students within the context of a very small rural school, the holistic view of the science student and their experience of science; and the aligning of the students' rural culture with culturally responsive pedagogy.

First, the investigation of science students within the specific context of a very small rural primary school increased the originality of my study. Previous studies on science students have focused on urban schools and larger rural schools. There is a paucity of research in the area of very small rural schools, therefore my study should contribute to our developing understanding of primary school science within the rural context.

Second, while existing literature has revealed themes and issues regarding aspects of primary school science students' attitudes, engagement, scientific skills, or scientific language, to the best of this researcher's knowledge there is no research that has examined all these concepts within the one study. My study has endeavoured to bring all these aspects together in order to present more of a holistic picture of the rural primary science student, in an attempt to present more of the totality and wholeness of their experience of learning science. As a result, my findings should enhance our knowledge of the variety of influences that can affect rural primary school science students within the science learning context.

Finally, the use of the *Tātaiako: Cultural Competencies for Teachers of Māori Learners* (Ministry of Education, 2011) to align the findings with culturally responsive pedagogy increased the originality of my study. Anecdotally, these competencies have been used in some schools as professional development resources in discussions on how to raise Māori student achievement, and in some cases, the achievement of all students in the school. To the best of my knowledge, these competencies have not been used as a way to align the culture of the school and pedagogical considerations specifically in the area of teaching of science. Therefore, I hope the findings of my study will interest other teachers and principals into considering this approach as a way to use the students' lifeworld to inform pedagogical practices of teachers and external providers of science programmes to enhance students' engagement, enjoyment and success with school science.

7.7 Autobiographical reflections

Undertaking this research whilst employed as a fulltime teaching principal has been an extremely rewarding learning experience. I have further developed my understanding of the nature of research, and come to appreciate research is not in fact orderly and sequential, but more a cyclical, ever reflective, and somewhat messy process. Throughout the research process I have at times felt like my science students examining a new science phenomenon for the first time, engaging in discovering anything and everything before the patterns begin to emerge. This is similar to how Roth (2005b) compares a student investigating a new science phenomenon for the first time to that of exploring an unknown, darkened room. I remained intrigued by the unknown and where the research would take me, tentatively confident in the knowledge that eventually it would all come together like a finished jigsaw puzzle. In this respect, it has been very beneficial to be personally engaged in this challenging learning experience as it reminds me of the complexity of the learning process students go through within the classroom setting.

Although this specific research investigation has come to a close, the insights, knowledge and understandings I have acquired will provide the incentive to continually examine my beliefs and attitudes towards teaching and learning in primary school science. I have begun to question how I come across as a science teacher to my students, whether they can see in me and my teaching some of the factors of influence that greatly impressed them about the scientists and the Chemistry Outreach programme, and whether they feel that their rural culture is acknowledged and affirmed within the schools' science programme. Since I now have a growing awareness of the importance of culturally responsive pedagogy in rural schools, I intend to explore my present school's culture with my staff and school community, and then align these cultural aspects with the relevant cultural competencies as detailed in *Tātaiako* (Ministry of Education, 2011). My aim is to use these competencies initially for science teaching and learning, but hopefully expand to all curriculum areas, in an effort to meet the learning needs of my rural students.

This study has reinforced the many benefits for both students and teachers involved in a partnership between the science community and the school, as experienced in the Chemistry Outreach programme. The opportunity to work with the Chemistry Outreach team has proved to be an invaluable experience for me as a rural primary school teaching principal. We worked together in a team-teaching format utilizing each other skills and expertise, namely Dr Dave Warren's and his team's content knowledge and my pedagogical and student knowledge, in a complimentary way to best meet the needs of the students. This meant access to the Chemistry Outreach's expertise, up to date scientific knowledge, advice, resources, and role models gave me the confidence to teach science the way I have always believed it should be taught - within an authentic, meaningful context, with plenty of hands-on experiences, and driven by the students themselves. The next step for me at my present school is to work alongside the students and the Chemistry Outreach team to facilitate a science learning environment which incorporates student agency and takes into account what this study has revealed about the Chemistry Outreach programme and the successful teaching and learning of science.

I have also begun to question our school's assessment science rubric, which was designed with several schools during our Professional Learning and Development contract. Of concern is the considerable emphasis placed on students' acquisition and usage of 'pure' science language. Now I am aware of the importance of everyday language as the initial step in students emerging use of scientific language, I intend to engage in professional discussions with these teaching colleagues with regards to the development of language, thought, and knowledge through engagement with the scientific phenomenon.

Furthermore, as I am now more aware of the importance of the social aspect in science learning and how group interactions can assist in developing students' science learning, I intend to be more deliberate and explicit in my use of small groups within my science programme. Finally, the research process has revealed a huge array of valuable resources and up to date research literature, which will assist both my staff and myself in improving the quality of our school's science programme.

7.8 Final comments

This study has provided a unique opportunity to listen to rural primary school students' voices as they talked in and about their lived experiences of the Chemistry Outreach programme. In doing so, they revealed effective scientific pedagogical practices from the rural students' perspective that incorporated a heads, hearts and hands-on approach to learning science. If we want to boost rural students' affective, behavioural and cognitive connections with science, it is important that we listen to their voices with our ears and our hearts, taking the time to first listen carefully before responding, to ensure our classroom pedagogy acknowledges and values their lived experiences as rural students living and learning within a rural community.

REFERENCES

Abrahams, I. (2009). Does practical work really motivate? A study of the affective vale of practical work in secondary school science. *International Journal of Science Education, 31*(17), 2335-2353.

Abruscato, J., & deRosa, D.A. (2010). *Teaching children science: Discovery methods for elementary and middle grades* (3rd ed.). Boston, MA: Pearson Education.

Aceves, T.C. & Orosco, M.J. (2014). *Culturally responsive teaching* (Document No. IC-2). Retrieved from http://ceedar.education.ufl.edu/tools/innovation-configurations/

Adúriz-Bravo, A., Chion, A.R., & Pujalte, A. P. (2015). Scientific language. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp. 1-4). DOI 10.1007/978-94-007-6165-0_262-1

Aikenhead, G. (1994). Consequences to learning science through STS: A research perspective. In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 169–186). New York, NY: Teachers College Press.

Aikenhead, G. (2005). *Science education for everyday life: Evidence-based practice*. New York, NY: Teachers College Press.

Ainley, M. (2012). Students' interest and engagement in classroom activities. In S.L. Christenson et al. (Eds.), *Handbook of research on student engagement,* (pp. 283-302). DOI 10.1007/978-1-4614-2018-7_13

Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology, 52,* 27-58.

Alderson, P., & Morrow, V. (2004). *Ethics, social research and consulting with children and young people.* Barkingside, England: Barbados.

Allan, K. (2014). *Linguistic meaning (RLE linguistics): A general linguistics.* Retrieved from http://www.eblib.com

Ambross, J., Meiring, L., & Blignaut, S. (2014). The implementation and development of science process skills in the natural sciences: A case study of teachers' perceptions. *African Education Review, 11*(3), 459-474.

Anderman, I.H. & Anderman, E.M. (1999). Social predictors of changes in students' achievement goal orientation. *Contemporary Educational Psychology, 24*(1), 21-37.

Anderson, M., & Lonsdale, M. (2014). Three Rs for rural research: Respect, responsibility and reciprocity. In S. White & M. Corbett (Eds.). *Doing educational* *research in rural settings: Methodological issues, international perspectives and practical solutions* (pp. 385-405). Hoboken, NJ: Taylor & Francis.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Anderson, D., Thomas, G.P., & Nashon, S.M. (2008). Social barriers to meaningful engagement in biology field trip group work. *Science Education, 93*(3), 511-534.

Andersson, H., & Bergman, L.R. (2011). The role of task persistence in young adolescence for succesful educational and occupational attainment in middle adulthood. *Developmental Psychology, 47*(4), 950-960.

Appleton, J.J., Christenson, S.L., & Furlong, M.J. (2008). Student engagement with school: Critical conceptual and methodological issues of the construct. *Pyschology in the Schools, 45,* 369-386.

Appleton, J.J., Christenson, S.L., Kim, D., & Reschly, A.L. (2006). Measuring cognitive and psychological engagement: Validation of the school engagement instrument. *Journal of School Psychology, 44,* 427-445.

Arnold, J. (2010). Science students' classroom discourse: Tasha's umwelt. *Research in Science Education, 42*(2), 233-259.

Arons, A.B. (1983). Achieving wider scientific literacy. *Journal of the American Academy of Arts and Sciences, 112*(2), 91-122.

Ash, D. (2008). Thematic continuities: Talking and thinking about adaptation in a socially complex classroom. *Journal of Research in Science Teaching, (45)*1, 1-30.

Ashworth, P.D. (1997). The variety of qualitative research. Part two: Non-positive approaches. *Nurse Education Today, 17,* 219-224.

Bakhtin, M.M. (1981). *The dialogic imagination.* Austin, TX: The University of Texas Press.

Ballenger, C. (1997). Social identities, moral narratives, scientific argumentation: Science talk in a bilingual classroom. *Language and Education, 11*(1), 1-14.

Barmby, P., Kind, P.M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education, 30,* 1075-1093.

Barton, A. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching, 35*(40), 379-394.

Barton, A., Ermer, L.L., Burkett, T.A., & Osborne, M.D. (2003). *Teaching science for social justice.* New York, NY: Teachers College Press.

Bell, B. (2005). *Learning in science: The Waikato research.* New York, NY: Routledge Falmer.

Bell, B. (2011). *Theorising teaching in secondary classrooms: Understanding our practice from a sociocultural perspective.* London, England: Routledge

Bell, R.L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction: Accessing the inquiry level of classroom activities. *The Science Teacher, 72*(2), 30-33.

Benitti, F. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers and Education, 58,* 978-988.

Bennett, J., & Hogarth, S. (2009). Would you want to talk to a scientist at a party? High school students' attitudes to school science and to science. *International Journal of Science Education, 31*(14), 1975-1998.

Bennett, J., Hogarth, S., Lubben, F., Campbell, B., & Robinson, A. (2010). Talking Science: The research evidence on the use of small group discussions in science teaching. *International Journal of Science Education, 32*(1), 69-95.

Bennett, J., Rollnick, M., Green, G., & White, M. (2001). The development and use of an instrument to assess students' attitude to the study of chemistry. *International Journal of Science Education, 23,* 833-845.

Bentz, V. M. & Shapiro, J. J. (1998). *Mindful enquiry in social research.* Thousand Oaks, CA: Sage.

Berg, B.L. (2001). *Qualitative Research Methods for Social Sciences* (4th ed.). Boston, MA: Allyn & Bacon.

Berne, B. (2014). Progression in ethical reasoning when addressing socio-scientific issues in biotechnology. *International Journal of Science Education, 36*(17), 2958-2977.

Berryman, M., Walker, R., Reweti, M., O'Brien, K., & Weiss, S. (2000). An ecological approach to understanding behaviour: Comprehensive and culturally appropriate strategies towards student success. *SET: Research Information for Teachers, 2,* 35-38.

Bertaux, D. (1981). *Biography and society: The life history approach in the social sciences.* Beverly Hills, CA: Sage.

Bianchini, J. (1997). Where knowledge construction, equity, and context intersect: Student learning of science in small groups. *Journal of Research in Science Teaching, 34,* 1039-1065.

Bielenia-Grajewska, M., & Gunstone, R. (2015). Language and learning science. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (1-9). DOI 10.1007/978-94-007-6165-0_262-1

Bilgin, I. (2006). The effects of hands-on activities incorporating a cooperative learning approach on eight grade students' science process skills and attitudes towards science. *Journal of Baltic Science Education, 1*(9), 27-37.

Bishop, R., & Berryman, M. (2009). The Te Kotahitanga Effective Teaching Profile. *SET: Research Information for Teachers, 2,* 27-33.

Bishop, R., Berryman, M., Cavanagh, T., & Teddy, L. (2007). *Te Kotahitanga Phase 3 Whanaungatanga: Establishing a culturally responsive pedagogy of relations in mainstream secondary school classrooms: Report to the Ministry of Education.* Wellington, New Zealand: Ministry of Education.

Bishop, R., Berryman, M., Tiakiwai, S., & Richardson, C. (2003). *Te Kotahitanga: The experiences of Year 9 and 10 Māori Students in mainstream classrooms: Report to the Ministry of Education.* Wellington, New Zealand: Ministry of Education.

Bishop R., & Glynn, T. (2000). Kaupapa Māori messages for the mainstream. *SET: Research Information for Teachers, 1,* 4-7.

Bishop, R., Berryman, M., Cavanagh, T., & Teddy, L. (2009). Te Kotahitanga: Addressing educational disparaties facing Māori students in New Zealand. *Teaching and Teacher Education, 25,* 734-742.

Bishop, R., Ladwig, J., & Berryman, M. (2014). The centrality of relationships for pedagogy: The *Whanaungatanga* thesis. *American Educational Research Journal, 51*(1), 184-214.

Blalock, C. L., Lichtenstein, M. J., Owen, S., Pruski, L., Marshall, C., & Toepperwein, M. (2008). In pursuit of validity: A comprehensive review of science attitude instruments 1935–2005. *International Journal of Science Education, 30,* 961–977.

Bloome, D., Puro, P., & Theodorou, E. (1989). Procedural display and classroom lessons. *Curriculum Inquiry, 19,* 265–291.

Bloor, M. (1997). Techniques of validation in qualitative research: A critical commentary. In G. Millar & R. Dingwall (Eds.). *Context and method in qualitative* research (pp. 37-50). London, England: Sage.

Bloor, M., Frankland, J., Thomas, M., & Robson, K. (2001). *Focus groups in social research.* London, England: Sage.

Bogdan, R., & Biklin, S.K. (1998). *Qualitative research in education: An introduction to theory and methods.* Boston, MA: Allyn and Bacon.

Bolstad, R., & Hipkins, R. (2008). Seeing yourself in science: The importance of the middle years. Retrieved from http://www.nzcer.org.nz/pdfs/16626.pdf

Bolstad, R. & Bull, A. (2013). *Strengthening engagements between schools and the science community.* New Zealand Council for Educational Research. Retrieved from http://www.nzcer.org.nz/system/files/Strengthening%20engagements%20between%20school%20.pdf

Bordt, M., De Broucker, P., Read, C., Harris. S., & Zhang, Y. (2001). Determinants of science and technology skills: Overview of the study. *Education Quarterly Review, 8*(1), 8-11.

Bowmar, A.M. (1997). *School culture and attitudes to science.* Unpublished Master of Education thesis, Massey University, Palmerston North, New Zealand.

Bragg, L.A. (2012). The effect of mathematical games on on-task behaviours in the primary classroom. *Mathematics Education Research Journal, 24,* 385-401.

Braund, M., & Driver, M. (2005). Pupils' attitudes to practical science around the KS2/3 transition. *Education 3-13*, 33(2), 20-26.

Breerer, K., & Bodzin, A.M. (2004, January). *Promoting inquiry-based science instruction: The validation of the science teacher inquiry rubric (STIR).* Paper presented at the 2004 Association for the Education of Teachers of Science (AETS) Annual Meeting, Nashville, TN. Retrieved from http://www.lehigh.edu/~amb4/stir/aets2004.pdf

Brewer, M. B., & Hewstone, M. (Eds.). (2004). *Social cognition*. Oxford, England: Blackwell Publishing.

Brotherton, P. & Preece, P. (1995) Science process skills: Their nature and interrelationships. *Research in Science & Technological Education, 13*(1), 5-11.

Brough, C. J. (2013). Transitioning from talking democratically, to thinking democratically and acting democratically: Exploring student-centred approaches to curriculum implementation. *SET: Research Information for Teachers, 2,* 11-20.

Brown, B. (2006). "It isn't no slang that can be said about this stuff": Language, identity, and appropriating science discourse. *Journal of Research in Science Teaching, 43*(1), 96-126.

Brown, R.A.J., & Renshaw, P. D. (2000). Collective argumentation: A sociocultural approach to reframing classroom teaching and learning. In H. Cowie & G. van der Aalsvoort (Eds.), *Social interaction in learning and instruction: The meaning of discourse for the construction of knowledge* (pp. 52–66). New York, NY: Pergamon.

Brown, B.A., & Ryoo, K. (2008). Teaching science as a language: A "content-first" approach to science teaching. *Journal of Research in Science Teaching, 45*(5), 529-553.

Brown, B.A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education, 92*(4)*,* 708-732.

Brown, D., & Thomson, C. (2000). *Cooperative learning in New Zealand schools*. Palmerston North, New Zealand: Dunmore Press.

Brown-Jeffry, S. & Cooper, J. E. (2011). Toward a conceptual framework of culturally relevant pedagogy: An overview of the conceptual and theoretical literature. *Teacher Education Quarterly, 38*(1), 65-84.

Bryk, A. S., & Schneider, B. (2002). *Trust in schools: A core resource for improvement.* New York, NY: Russell Sage Foundation.

Bryman, A. (2007). Barriers to integrating quantitative and qualitative research. *Journal of Mixed Methods Research, 1,* 8-22.

Bull, A., Gilbert, J., Barwick., Hipkins. R., & Baker, R. (2010) *Inspired by Science.* A paper commissioned by the Royal Society and the Prime Minister's Chief Science Advisor. Wellington, New Zealand: NZCER

Bunterm, T., Lee, K., Kong, J.N.L., Srikoon, S., Vangpoomyai. P., Rattanavongsa & Rachahoon, G. (2014). Do different levels of inquiry lead to different learning outcomes? A comparison between guided and structured inquiry. *International Journal of Science Education, 36*(12), 1937-1959.

Butler, M.B., & Nesbit, C.N. (2008). Using science notebooks to improve writing skills and conceptual understanding. *Science Activities, 44*(4), 137-145.

Byrne, M., Johnstone, A.H., & Pope, A. (1994). Reasoning in science: A language problem revealed? *School Science Review, 75*(272), 103-107.

Caleon, I. S., & Subramaniam, R. (2008). Attitudes towards science of intellectually gifted and mainstream upper primary students in Singapore. *Journal of Research in Science Teaching, 45*(8), 940–954.

Çalık, M. (2005). A cross-age study of different perspectives in solution chemistry from junior to senior high school. *International Journal of Science and Mathematics Education*, *3,* 671-696.

Campbell, A., & Otrel-Cass, K. (2011). Teaching evolution in New Zealand's schools - reviewing changes in the New Zealand Science Curriculum. *Research in Science Education, 41,* 441-451.

Capella, E., Kim, H.Y., Neal, W.N., & Jackson, D.R. (2013). Classroom peer relationships and behavioural engagement in elementary school: The role of social network equity. *American Journal Community Psychology, 52,* 367-379.

Carlsen, W.S. (2007). Language and science learning. In S.K. Abell and N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 57-74). Mahwah, NJ: Lawrence Erlbaum Associates.

Carpenter, V.M. & Duhn, I. (2012). Editorial. *New Zealand Journal of Educational Studies, 47*(1), 1-3.

Cassels, J., & Johnstone A. (1985). *Words that matter in science.* London, England: Royal Society of Chemistry.

Caygill, R. (2008). *Science: Trends in year 5 science achievement 1994 to 2006.* Wellington, New Zealand: Ministry of Education.

Cazden, C.B. (2001). *Classroom discourse: The language of teaching and learning.* Portsmouth, NH: Heinemann.

Cerbone, D. R. (2006). *Understanding phenomenology.* Stocksfield, England: Acumen.

Chamberlain, M. & Caygill, R. (2013). *Key findings from New Zealand's participation in the Progress in International Reading Literacy Study (PIRLS) and Trends in International Mathematics and Science Study (TIMSS) in 2010/11.* Wellington, New Zealand: Ministry of Education.

Chapman, B. (1993). The overselling of science education in the eighties. In E. Whitelegg, J. Thomas and S. Tresman (Eds), *Challenges and Opportunities for Science Education* (pp. 256-277). London, England: Paul Chapman.

Charlesworth, R., & Lind, K.K. (2003). *Math and science for young children.* Clifton Park, NY: Delmar Learning.

Chatterjee, S., Williamson, V.M., McCann, K., & Peck, M.L. (2009). Surveying students' attitudes and perceptions toward guided-inquiry and open-inquiry laboratories. *Journal of Chemical Education, 86*(12), 1427-1432.

Chen, Y., Hand, B., & McDowell, L. (2013). The effects of writing-to-learn-activities on elementary students' conceptual understanding: Learning about force and motion through writing to older peers. *Science Education, 97*(5), 745-771.

Chin, C. & Osborne, J. (2008). Students' questions: A potential resource for teaching and learning. *Studies in Science Education, 44*(1), 1-39.

Chinn, C.A., & Hmelo-Silver, C.E. (2002). Authentic inquiry: Introduction to the special section. *Science Education, 86*(2), 171-174.

Chinn, C.A., & Malhotra, B.A. (2002). Epistemologically authentic inquiry in school: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*(2), 175-218.

Christians, C.G. (2011). Ethics and politics in qualitative research. In N.K. Denzin & Y.S. Lincoln (Eds.). *The Sage handbook of qualitative research* (pp. 61-80). California, CA: Sage.

Cleary, R.E. (2004). The no child left behind act of 2002: Is it helping or hurting education in the United States? Retrieved from http://www.cosmosclub.org/web/journals/2004/cleary.html

Cohen, E. (1997). Working for equity in heterogeneous classrooms: Sociological theory in practice. In E. Cohen & R. Lotan (Eds.), *Understanding status problems: Sources and consequences* (pp. 61-76). New York, NY: Teachers College Press.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. New York, NY: Routledge.

Collins, K.M., Palinscar, A.S., & Magnusson, S.J. (2005). Science for all: A discursive analysis examining teacher support of student thinking in inclusive classrooms. In R.Yerrick & W-M. Roth (Eds.), *Establishing scientific classroom discourse communities: Multiple voices of teaching and learning research* (pp. 199-224). Mahwah, NJ: Lawrence Erlbaum Associates.

Colville, M., & Pattie, I. (2002a). Science skills: The building blocks. *Investigating, 18*(4), 27-30.

Colville, M., & Pattie, I. (2002b). Science skills: The building blocks for scientific literacy. *Investigating, 18* (3), 20-22.

Connolly, P. (2008). Race, gender and critical reflexivity in research with young children. In P. Christensen and A. James (Eds.), *Research with children: Perspectives and practices* (pp.173-218). London, England: Routledge Falmer

Cooper, B., Cowie, B., & Jones, A (2011). Connecting teachers and students with science and scientists: The Science Learning Hub. *Science Education International 21*(2), 92-101.

Corbett, M., & White, S. (2014). Introduction: Why put 'rural' in research? In S. White & M. Corbett (Eds.). *Doing educational research in rural settings: Methodological issues, international perspectives and practical solutions* (pp. 26-31). Hoboken, NJ: Taylor & Francis.

Cowie, B., Jones, A., & Otrel-Cass, K. (2011). Re-engaging students in science: Issues of assessment, funds of knowledge and sites for learning. *International Journal of Science and Mathematics Education, 9,* 347-366.

Cornelius-White, J. (2007). Learner-centred teacher-student relationships are effective: A meta-analysis. *Review of Educational Research, 77*(1), 113-143.

Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics 113*(5), 215-226.

Cotterill, P. (1992). Interviewing women: Issues of friendship, vulnerability, and power. *Women's Studies International Forum, 15,* 593-606.

Crano, W.D. & Prislin, R. (2006). Attitudes and persuasion. *Annual Review of Psychology, 57,* 345-374

Crawford, T., Kelly, G.J., & Brown, C. (2000). Ways of knowing beyond facts and laws of science: An ethnographic investigation of student engagement in scientific practices. *Journal of Research in Science Teaching, 37*(3), 237-258.

Creswell, J.W. (2009). *Research design: Qualitative, quantitative and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Crooks, T., & Flockton, L. (1996). *Science assessment results 1995.* Dunedin, New Zealand: The Educational Assessment Research Unit, University of Otago.

Crooks, T., & Flockton, L. (2000). *Science assessment results 1999.* Dunedin, New Zealand: The Educational Assessment Research Unit, University of Otago.

Crooks, T., & Flockton, L. (2001). *Mathematics: Assessment Results 2001*. Dunedin, New Zealand: The University of Otago.

Crooks, T., & Flockton, L. (2004). *Science assessment results 2003.* Dunedin, New Zealand: The Educational Assessment Research Unit, University of Otago.

Crooks, T., Smith, J., & Flockton, L. (2008). *Science assessment results 2007.* Dunedin, New Zealand: The Educational Assessment Research Unit, University of Otago.

Crotty, M. (1996). *Phenomenology and nursing research.* South Melbourne, Australia: Churchill Livingstone.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process.* London, England: Sage.

Cushman, K., & Rogers, L. (2008). Middle school students talk about social forces in the classroom. *Middle School Journal, 39*(3), 14-24.

Dall'Alba, G. (2009). Introduction to diverse approaches to phenomenology and education. In G. Dall'Alba (Ed.). *Exploring education through phenomenology: Diverse approaches* (pp. 1-3). West Sussex, England: Wiley-Blackwell.

Darby, L. (2005). Science students' perceptions of engaging pedagogy. *Research in Science Education, 35,* 425-445.

Dawes, L. (2004). Research report: Talk and learning in classroom science. *International Journal of Science Education, 26*(6), 677-695.

Delpit, L. (1998). The silenced dialogue: Power and pedagogy in educating other peoples' children. *Harvard Educational Review, 58*, 280-298.

den Brok, P., Fisher, D., & Scott, R. (2005). The importance of teacher interpersonal behaviour for student attitudes in Brunei primary science classes. *International Journal of Science Education, 27*(7), 765-779.

Denzin, N. K. & Lincoln, Y. S. (2011). Introduction: The discipline and practice of qualitative research. *The Sage handbook of qualitative research* (4th ed., pp. 1-19). Thousand Oaks, CA: Sage.

Dökme, I., & Aydinli, E. (2009). Turkish primary school students' performance on basic science process skills. *Procedia Social and Behavioural Sciences, 1,* 544-548.

Domenech, A.M. & Marquez, C. (2014). Which perspectives are referred in students' arguments about a socio-scientific issue? The case of bears' reintroduction in the Pyrenees. In C. Bruguiere, A. Tiberghien, & P. Clement (Eds.), *Topics and trends in current science education* (pp. 71-84). Dordrecht, Netherlands: Springer.

Dunleavy, J., Milton, P., & Crawford, C. (2010). The search for competence in the 21st century. Retrieved from www.yrdsb.ca/Programs/PLT/Quest/Journal/2010-Search-for-Competence-in-the-21st-Century.pdf

Duschl, R.A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*, 39-72.

Duschl, R., Schweingruber, H.A., & Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades K-8.* Washington, DC: The National Academies Press.

Easton, K.L., McComish, J.F., & Greenberg, R. (2000). Avoiding common pitfalls in qualitative data collection and transcription. *Qualitative Health Research, 10*(5), 703-707.

Eccles, J. & Wang, M. (2012). Part 1 commentary: So what is student engagement anyway? In S.L. Christenson, A. L. Reschley & C. Wylie (Eds.). *Handbook of research on student engagement* (pp. 131-145). DOI 10.1007/978-1-4614-2018-7_6

Eder, D., & Fingerson, L. (2001). Interviewing children and adolescents. In J.F. Gubrium & J.A. Holstein (Eds.). *Handbook of Interview Research.* pp. 181-201. London, England: Sage.

Education Review Office (2004). *The Quality of Teaching in Years 4 and 8: Science.* Retrieved from http://www.ero.govt.nz/National-reports/The-Quality-of-teaching-in-Years-4and-8-Science

Education Review Office (2012). *Science in the New Zealand Curriculum: Years 5 to 8.* Retrieved from www.ero.govt.nz/National-Reports/Science-in-The-New-Zealand-Curriculum-Years-5-to-8-May-2012

Education Review Office (2015). *Wellbeing for children's success at primary school (February 2015).* Retrieved from ero.govt.nz/National-Reports/Wellbeing-for-Children's-Success-at-Primary-School-February-2015

Eijkelhof, H., & Voogt, P. (2001). Netherlands. In M. Poisson (Ed.), *Science education for contemporary society: Problems, issues and dilemmas* (pp. 93–98). Geneva, Switzerland: International Bureau For Education, UNESCO.

Eilks, I., Nielsen, J., & Hofstein, A. (2013). Learning about the role and function of science in public debate as an essential component of scientific literacy. In C. Bruguiere, A. Tiberghien, & P. Clement (Eds.), *Topics and Trends in Current Science Education* (pp. 85-100). Dordrecht, Netherlands: Springer.

Einarsdóttir, J. (2007). Research with children: Methodological and ethical challenges. *European Early Childhood Research Journal, 15*(2), 197-211.

Elliot, K., & Paige, K. (2010). Middle year students talk: Science sux or science rocks! *Teaching Science, 56*(1), 13-16.

Ergül, R., Simsekli, Y., Calis, S., Özdilek, Z., Göçmençelebi, S., & Sanli, M. (2011). The effects of inquiry-based science teaching on elementary school students' science process skills and science attitudes. *Bulgarian Journal of Science and Education Policy (BJSEP), 5*(1), 48-68.

Evagorou M., & Osborne, J. (2010). The role of language in the learning and teaching of science. In J. Osborne & J. Dillon (Eds.), *Good practice in science teaching: What research has to say* (2nd ed., pp. 135-157). Buckingham, England: Open University Press.

Fang, Z. (2006). The language demands on science reading in middle school. *International Journal of Science Education, 28*(5), 491-520.

Feasey, R. (2012). Thinking and working scientifically. In K. Skamp (Ed.). *Teaching primary science constructively* (4th ed., pp. 55-98). Victoria, Australia: Cengage Learning.

Feasey, R. (2015). Thinking and working scientifically. In K.Skamp & C. Preston (Eds.) *Teaching primary science constructvely* (5th ed., pp 79-117). Victoria, Australia: Cengage Learning.

Feasey, R., & Gallear, R. (2000). *Primary science and numeracy.* Hatfield, England:ASE

Fensham, P.J. (2007). Interest in science: Lessons and non-lessons from TIMSS and PISA. In R. Pinto & D. Couso (Eds.), *Contributions from science education research* (pp. 3-10). Dordrecht, Netherlands: Springer.

Finn, J. D. (1993). *School engagement and students at risk.* Washington, D.C: National Centre for Education Statistics.

Finn, J. D. (2006). *The adult lives of at-risk students: The roles of attainment and engagement in high school* (NCES 2006-328). Washington, D.C.: National Centre for Educational Statistics, U.S. Department of Education.

Finn, J. D., & Zimmer, K.S. (2012). Student engagement: What is it? What does it matter? In S.L. Christenson, A.L. Reschly & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 97-131). Dordrecht, Netherlands: Springer.

Fisher, E. (1993). Distinctive features of pupil-pupil classroom talk and their relationship to learning: How discursive exploration might be encouraged. *Language and Education 7*(4), 239-257.

Fitzgerald, A. (2012). Teaching for student engagement in science. In A. Fitzgerald (Ed.), *Science in primary schools: Examining the practices of effective primary science teachers* (pp. 37-51). Rotterdam, Netherlands: Sense Publishers.

Fitzgerald, A., Hackling, M., & Dawson, V. (2013). Through the viewfinder: Reflecting on the collection and analysis of classroom video data. *International Journal of Qualitative Methods 12,* 52-64.

Flick, L., & Bell, R. (2000). *Preparing tomorrow's science teachers to use technology: Guidelines for science educators. Contemporary Issues in Technology and Teacher Education* [Online serial], 1 (1). Retrieved from http://www.citejournal.org/vol1/iss1/currentissues/science/ article1.htm

Forbes, G. A. (2014). *MyScience: Communities of practice around the teaching and learning of primary science.* Unpublished doctoral dissertation, Southern Cross University, Lismore, New South Wales, Australia.

Foucault, M. (1977). *Discipline and Punish: The birth of the prison.* London, England: Allen Lane.

Francis, R.W. (1996). Connecting the curriculum through the National Mathematics and Science Standards. *Journal of Science Teacher Education, 7*(1), 75-81.

Francis, L.J., & Greer, J.E. (1999). Measuring attitude towards science among secondary school students: The affective domain. *Research in Science and Technological Education, 17*(2), 219-226.

Fraser, D. (2000). Curriculum integration: What it is and what is not. *SET: Research Information for Teachers, 3,* 34-37.

Fredricks, J.A., Blumenfeld, P.C., & Paris, A.H. (2004). School Engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59-109.

Fredricks, J.A. & McCloskey, W. (2012). The measurement of student engagement: A comparative analysis of various methods and student self-report instruments. In S.L. Christenson, A.L. Reschly & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 763-782). Dordrecht, Netherlands: Springer.

Friedl, A.E. & Koontz, T.Y. (2005). *Teaching science to children: An inquiry approach* (6th ed.). New York, NY: McGraw-Hill

Frost, N. (2011). *Qualitative research methods in psychology: Combining core appraoches.* New York, NY: Open University Press.

Frowe, I. (2001). Language and educational research. *Journal of Philosophy and Education, 35*(2), 175-186.

Frymier, A.B., & Houser, M.L. (2000). The teacher-student relationship as an interpersonal relationship. *Communication Education, 49*(3), 207-219.

Furlong, M.J., & Christenson, S.L. (2008). *Psychology in the Schools, 45*(5), 365-368.

Gabel, L.D. (1993). *Introductory science skills* (2nd ed.). U.S.A: Waveland.

Gallas, K. (1994). *The languages of learning: How children talk, write, dance, draw and sing their understanding of the world.* New York, NY: Teachers College Press.

Gallas, K. (1995). *Talking their way into science: Hearing children's questions and theories, responding with curricula.* New York, NY: Teachers College Press.

Garbarino, J. (2010). The right to a healthy social environment: Protecting children from social toxicity. In J. Garbarino & G. Sigman (Eds.), *A child's right to a healthy environment* (pp. 245-252). Dordrecht, Netherlands: Springer

Garbett, D. (2011). Developing pedagogical practices to enhance confidence and competence in science teacher education. *Journal of Science Teacher Education, 22,* 729-743.

Gay, G. (2000). *Culturally responsive teaching: Theory, research, and practice*. New York, NY: Teachers' College Press.

Ge, X., & Land, S. M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research Development, 52*(2), 5-22.

Gee, J. P. (1999). *An introduction to discourse analysis: Theory and method.* New York, NY: Routledge.

Gee, J. P. (2004). Language in the science classroom: Academic social languages as the heart of school-based literacy. In W. Saul (Ed.), *Crossing borders in literacy and science instruction: Perspectives on theory and practice* (pp. 10–32). Newark, DE: International Reading Association.

Gee, J. P. (2005). Language in the science classroom: Academic social languages as the heart of school-based literacy. In R. Yerrick & W-M. Roth (Eds.), *Establishing scientific classroom discourse communities: Multiple voices of teaching and learning research.* (pp. 19-37). Mahwah, NJ: Lawrence Erlbaum Associates.

George, R. (2000). Measuring change in students' attitudes toward science over time: An application of latent variable growth modeling. *Journal of Science Education and Technology, 9*(3), 213-225.

George, R. (2006). A cross-domain analysis of change in students' attitudes towards science and attitudes about the utility of science. *International Journal of Science Education, 28*(6), 571-589.

Gibbs, C. (2006). *To be a teacher: Journeys towards authenticity.* Auckland, New Zealand: Pearson New Zealand.

Gibbs, R., & Poskitt, J. (2010). *Student engagement in the middle years of schooling (Years 7-10): A literature review.* Report to the Ministry of Education. Retrieved from www.educationcounts.govt.nz/publications

Giles, D., Smythe, E., & Spence, D. (2012). Exploring relationships in education: A phenomenological inquiry. *Australian Journal of Adult Learning, 52*(2), 214-236.

Gluckman, P. (2011). *Looking ahead: Science education for the twenty-first century.* A report from the Prime Minister's Chief Science Advisor. Auckland, New Zealand: Office of the Prime Minister's Science Advisory Committee.

Glynn, T., Cowie, B., Otrel-Cass, K., & MacFarlane, A. (2010). Culturally responsive pedagogy: Connecting New Zealand teachers of science with their Māori students. *The Australian Journal of Indigenous Education, 39,* 118-127.

Goldstein, L. (1998). More than gentle smiles and warm hugs: Applying the ethic of care to early childhood education. *Journal of Research in Childhood Education, 12,* 244-61.

Goodenough, T., Williamson, E., Kent, J., & Ashcroft, R. (2003). "What did you think about that?" Researching children's perceptions of participation in a longitudinal genetic and epidemiological study. *Children and Society, 17,* 113-125.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools*. Canberra, Australia: Department of Education, Training and Youth Affairs.

Gopnik, A. (2012). Scientific thinking in young children: Theoretical advances, empirical research, and policy implications. *Science 337,* 1623-1627.

Goto, M. (2001). Japan. In M. Poisson (Ed.), *Science education for contemporary society. Problems, issues and dilemmas.* Final report of the international workshop on the reform in the teaching of science and technology at the primary and secondary level in Asia: Comparative references to Europe (pp. 31–38). Geneva, Switzerland: International Bureau For Education, UNESCO.

Gott, R. & Duggan, S. (1995). *Developing science and technology education investigative work in the science curriculum.* Buckingham, England: Open University Press.

Gott, R., & Duggan, S. (2007). A framework for practical work in science and scientific literacy through argumentation. *Research in Science and Technological Education, 25*(3), 271-291.

Graham, A., & Fitzgerald, R. (2010). Children's participation in research: Some possibilities and constraints in the current Australian research environment. *Journal of Sociology, 46*(2), 133-147.

Grazier, N., & Meade, A. (n/d). *How children learn about responsibility "Tuakana-teina."* Retrieved from www.daisies.co.nz/daisies-publications-responsibilities.pdf

Gristy, C. (2012) The central importance of peer relationships for student engagement and well-being in a rural secondary school. *Pastoral Care in Education: An International Journal of Personal, Social and Emotional Development, 30*(3), 225-240.

Guba, E. G., & Lincoln, Y. S. (2005). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed., pp. 191-216). Thousand Oaks, CA: Sage.

Guthrie, J.T., & Wigfield, A. (2000). Engagement and motivation in reading. In M. Kamil & P. Mosenthal (Eds.), *Handbook of Reading Research* (pp. 403-422). Mahwah, NJ: Lawrence Erlbaum.

Gutierrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher, 32,* 19-25.

Hackling, M., Smith, P., & Murcia, K. (2010). Talking science: Developing a discourse of inquiry. *Teaching Science, 56*(1), 17-22.

Halliday, M.A.K. (1993). Towards a language-based theory of learning. *Linguistics and Education, 5,* 93-116.

Halliday, M.A.K. & Martin, J.R. (1993). *Writing science: Literary and discursive power.* London, England: Falmer.

Hardin, P.K. (2003). Constructing experience in individual interviews, autobiographies and on-line accounts: A poststucturalist approach. *Journal of Advanced Nursing, 41*(6), 536-544.

Hargreaves, L. (2009). Respect and responsibility: Review of research on small rural schools in England. *International Journal of Educational Research, 48,* 117-128.

Harlen, W. (1999). Purposes and procedures for assessing science process skills. *Assessment in Education, 6*(1), 129-144.

Harlen, W. (2000). *Teaching, learning and assessing science* (3rd ed). London, England: Paul Chapman Publishing.

Harlen, W. (2012). What do we know about the learners' ideas at the primary level? In J. Oversby (Ed.), *ASE Guide to Research in Science Education* (pp. 44-50). Hatfield, England: Association for Science Education.

Haste, H. (2004). *Science is my future: A study of values and beliefs in relation to science and technology amongst 11-21 year olds*: Nestle Social Research Programme.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement.* London, England: Routledge.

Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning.* New York, NY: Routledge.

Hendrick, H. (2008). The child as a social actor in historical sources: Problems of identification and interpretation. In P. Christensen and A. James (Eds.), *Research with Children: Perspectives and practices* (2nd ed., pp. 40-65). London, England: Falmer Press.

Hendley, D., Parkinson, J., Stables, A., & Tanner, H. (1995). Gender differences in pupil attitudes to the national curriculum foundation subjects of english, mathematics, science and technology in Key Stage 3 in South Wales. *Educational Studies, 21,* 85-97.

Henriksson, C. (2008). *Living away from blessings. School failure as lived experience.* London, Ontario: The Althouse Press.

Henriksson, C. (2012). Hermeneutic Phenomenology and pedagogical practice. In N. Frieson, C. Henriksson & T. Saevi (Eds.). *Hermeneutic phenomenology in education: Method and practice* (pp 119-140). Rotterdam, Netherlands: Sense.

Henriksson, C., & Friesen, N. (2012). Introduction. In N. Friesen, C. Henriksson, & T. Saevi (Eds.). *Hermeneutic phenomenology in education: Method and practice* (pp. 1-16). Rotterdam, The Netherlands: Sense.

Hektner, J. M., Schmidt, J. A., & Csikzentmihalyi, M. (2007). *Experience sampling method: Measuring the quality of everyday life.* Thousand Oaks, CA: Sage.

Hill, G., Atwater, M., & Wiggins, J. (1995). Attitudes toward science of urban seventh-grade life science students overtime, and the relationship to future plans, family, teacher, curriculum, and school. *Urban Science, 30,* 71-92.

Hipkins, R. (2012). *Building a science curriculum with an effective nature of science component.* Wellington, New Zealand: New Zealand Council for Educational Research.

Hipkins, R., Bolstad, R., Baker, R., Jones, A., Barker, M., Bell, B., Coll, R., Cooper, B., Forret, M., Harlow, A., Taylor, I., France, B., & Haigh, M. (2002). *Curriculum, learning and effective pedagogy: A literature review in science education.* Wellington, New Zealand: Ministry of Education.

Hipkins, R., Roberts, J., Bolstad, R., & Ferral, H. (2006). *Staying in science 2*. Wellington: Ministry of Research, Science and Technology.

Holloway, I. (1997). *Basic concepts for qualitative research.* Oxford, England: Blackwell Science.

Howe, C., & Abedin, M. (2013). Classroom dialogue: A systematic review across four decades of research. *Cambridge Journal of Education, 43*(3), 325-356.

Hudicourt-Barnes, J. (2003). The use of argumentation in Haitian Creole science class-rooms. *Harvard Educational Review, 73*(1), 73-93.

Huerta, M., Irby, B.J., Lara-Alecio, R., & Tong, F. (2015). Relationship between language and concept science notebook scores of English language learners and/or economically disadvantaged students. *International Journal of Science and Mathematics Education, 13,* 1-17.

Hycner, R. H. (1999). Some guidelines for the phenomenological analysis of interview data. In A. Bryman & R. G. Burgess (Eds.), *Qualitative Research* (pp. 143-164). London, England: Sage.

Jadrich, J., & Bruxvoort, C. (2011). *Learning and teaching scientific inquiry: Research and applications.* Arlington, VI: National Science Teachers Association.

Jenkins, E.W. & Nelson, N.W. (2005). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science and Technological Education, 23*(1), 41-57.

Jiménez-Aleixandre, M.P., & Erduran, S. (2008). Argumentation in science education: An overview. In S. Erduran, & M.P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom based research* (pp. 3-27). Dordrecht, Netherlands: Springer.

Jiménez-Aleixandre, M.P., Rodríguez, A.B., & Duschl, R.A. (2000). 'Doing the lesson' or 'doing science': Argument in high school genetics. *Science Education, 84,* 757-792.

Jimerson, S. R., Campos, E., & Greif, J. L. (2003). Toward an understanding of definitions and measures of school engagement and related terms. *California School Psychologist, 8*, 7-27.

Jones, C. (2000). The role of language in the learning and teaching of science. In M. Monk and J. Osborne (Eds.), *Good practice in science teaching: What research has to say* (pp. 88-103). Buckingham, England: Open University Press.

Kalvaitis, D., & Monhardt, R.M. (2012). The architecture of children's relationships with nature: A phenomenographic investigation seen through drawings and written narratives of elementary students. *Environmental Education Research, 18*(2), 209-227.

Kamberelis, G., & Dimitriadis, G. (2011). Focus groups: Contingent articulations of pedagogy, politics and inquiry. In N.K. Denzin & Y.S. Lincoln (Eds.), *The Sage handbook of qualitative research* (4th ed., pp. 545-562). Thousand Oaks, CA: Sage.

Karnieli-Miller, O., Strier, R & Pessach, L. (2009). Power relations in qualitative research. *Qualitative Health Research, 19*(2), 279-289.

Kaya, V.H., Bahceci, D., & Altuk, Y, G. (2012). The relationship between primary school students' scientific literacy levels and scientific process skills. *Procedia-Social and Behavioral Sciences, 47,* 495-500.

Kelly, G.J. (2007). Discourse in science classrooms. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 443-465). Malwah, NJ: Lawrence Erlbaum Associates.

Kelly, G. J., & Brown, C. (2003). Communicative demands of learning science through technological design: Third grade students' construction of solar energy devices. *Linguistics and Education, 13*(4), 483-532.

Kelly, G. J., & Crawford, T. (1997). An ethnographic investigation of the discourse processes of school science. *Science Education, 81*, 533-559.

Kennish, P., & Cavanagh, R. (2009). *How engaged are they? An inductive analysis of country student views of their engagement in classroom learning.* Paper submitted to the 2009 Annual Conference of the Australian Association for Research in Education: Canberra, Australia.

Kerr, K. & Murphy, C. (2012). Children's attitudes to primary science. In B.J. Fraser, K. Tobin & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 627- 649). Dordrecht, Netherlands: Springer. doi: 10.1007%2F978-1-4020-9041-7_42

Ketelhut, D. J., & Dede, C. (2006). *Assessing inquiry learning.* Paper presented at the

National Association of Research in Science Teaching Annual Meeting, San Francisco, CA.

Khan, B. H. (1997). *Web-based instruction*. New Jersey: Educational Technology Publications.

Kind, P., Jones, K. & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education 29*(7), 871-893.

Kirch, S.A. (2007). Re/Production of science process skills and a scientific ethos in an early childhood classroom. *Cultural Studies of Science Education 2*(4), 785-845.

Kirk, S. (2007). Methodological and ethical issues in conducting qualitative research with children and young people: A literature review. *International Journal of Nursing Studies, 44,* 1250-1260.

Klein, P.D. (1998). The role of children's theory of mind in science experimentation. *The Journal of Experimental Education*, *66*(2), 101-124.

Koballa Jr T.R. & Glynn, S.M. (2007). Attitudinal and motivational constructs in science learning. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 75-102). Mahwah, NJ: Lawrence Erlbaum.

Knaggs, C.M., & Schneider, R.M. (2012). Thinking like a scientist: Using vee-maps to understand process and concepts in science. *Research in Science Education, 42*(4), 609-632.

Koksal, E.A., & Berberoglu, G. (2014). The effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills and attitudes toward science. *International Journal of Science Education, 36*(1), 66-78.

Kowal, S., & O'Connell, D.C. (2004). The transcriptions of conversations. In U. Flick, E. von Kardoff & I. Steinke (Eds.), *A Companion to Qualitative Research* (pp. 248-252). London, England: Sage.

Kuhn, D., & Dean, D. (2005). Is developing scientific thinking all about learning to control variables? *Psychological Science, 16,* 866-870.

Kukkonen, J.E., Kärkkäinen, S., Dillon, P., & Keinonen, T. (2014). The effects of scaffolded simulation-based inquiry learning on fifth-graders' representations of the greenhouse effect. *International Journal of Science Education, 36*(3), 406-424.

Kvale, S. (1996). *Interviews: An introduction to qualitative research interviewing*. Thousand Oaks, California: Sage.

Ladson-Billings, G. (1995a). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into Practice, 34*(3), 159-165.

Ladson-Billings, G. (1995b). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465-491.

Lam, S., Wong, B. P. H., Shin, H., Hatzichristou, C., Polychroni, F., Negovan, V., Stanculescu, E., Liu, Y., Duck, R., Nelson, B., Jimerson, S., Kikas, E., Veiga, F. H., Cefai, C., Yang, H., Basnett, J., & Zollneritsch, J. (2014). Understanding and measuring student engagement in school: The results of an international study from 12 countries. *School Psychology Quarterly, 29*(2), 213-232.

Laverty, S.M. (2003). Hermeneutic phenomenology and phenomenology: A comparison of historical and methodological considerations. *International Journal of Qualitative Methods, 2*(3), 21-35.

Lawson, A.E. (1985). A review of research on formal reasoning and science teaching. *Journal of Research in Science Teaching, 22*(7), 569-617.

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research, 75*(4), 491-530.

Lee, O., & Anderson, C.W. (1993). Task engagement and conceptual change in middle school science classrooms. *American Educational Research Journal, 30,* 585-610.

Lee, O., & Fradd, S. H. (1996). Interactional patterns of linguistically diverse students and teachers: Insights for promoting science learning. *Linguistics and Education: An International Research Journal, 8*(3), 269-297.

Lee, O., & Fradd, S. H. (1998). Science for all, including students from non-English - language backgrounds. *Educational Researcher, 27,* 651-671.

Lemke, J. L. (1993). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Lilja, A. (2013). Body, space and time and their influences on trustful relationships in the classroom. *Indo-Pacific Journal of Phenomenology, 13*, 1-10.

Lind, K.K. (2005). *Exploring science in early childhood education* (4th ed.). Clifton Park, NY: Thomson Delmar Learning.

Lindahl, B. (2003). *Pupils' responses to school science and technology? A longitudinal study of pathways to upper secondary school. A summary of my thesis*. Retrieved from http://www.mna.hkr.se/~ll/summary.pdf

Lindfors, J.W. (1999). *Children's inquiry: Using language to make sense of the world.* New York, NY: Teachers College Press.

Lindsay, G. (2000). Researching children's perspectives: Ethical issues. In A. Lewis & G. Lindsay (Eds.), *Researching children's perspectives* (pp. 34-45). Buckingham, England: Open University Press.

Linnenbrink, E. A., & Pintrich, P. R. (2003). The role of self-efficacy beliefs in student engagement and learning in the classroom. *Reading and Writing Quarterly, 19*(2), 119-137.

Litosseliti, L. (2003). *Using focus groups in research.* London, England: Continuum.

Logan, M. & Skamp, K. (2008). Engaging students in science across the primary secondary interface: Listening to the students' voice. *Research in Science Education, 38*(4), 501-527.

Logan, M. & Skamp, K. (2013). The impact of teachers and their science teaching on students' 'science interest': A four-year study. *International Journal of Science Education, 35*(17), 2879-2904.

Lyons, T. (2003). *Decisions by science proficient Year 10 students about post-compulsory high school science enrolement: A sociocultural exploration*. Unpublished PhD. thesis, University of New England, Armidale, New South Wales, Australia.

Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591-613.

McKinley, E. (2005). Locating the global: Culture, language and science education for indigenous students. *International Journal of Science Education, 27*(2), 227-241.

Macfarlane, A. (2004). *Kia hiwa ra! Listen to culture: Māori students' plea to educators.* Wellington, New Zealand: New Zealand Council for Educational Research.

McMorran, D., & Warren, D. (2012). Taking chemistry out of the lab: Perspective on Chemistry OutReach at Otago. *Chemistry in New Zealand* April 2012. Retrieved from nzic.org.nz/CiNZ/articles/CiNZ%20Apr%202012_mcmorran.pdf.

Maeng, S., & Kim, C-J. (2011). Variations in science teaching modalities and students' pedagogical subject positioning through the discourse register and language code. *Science Education, 95*(3), 431-457.

Mallow, J., Kastrup, H., Bryant, F.B., Hislop, N., Shefner, R. & Udo, M. (2010). Science anxiety, science attitudes, and gender: Interviews from a binational study. *Journal of Science Education and Technology, 19*(4), 356-369.

Mant, J., Wilson, H., & Cates, D. (2007). The effect of increasing conceptual challenge in primary school lessons on pupils' achievement and engagement. *International Journal of Science Education, 29*(14), 1707-1719.

Marks, H.M. (2000). Student engagement in instructional activity: Patterns in elementary, middle and high school years. *American Education Research Journal, 37*(1), 153-184.

Marshall, S., Gilmour, M., & Lewis, D. (1991). Words that matter in science and technology. *Research in Science and Technological Education, 9*(1), 5-16.

Martin, M.O., Mullis, I.V.S., & Foy, P. (2008). *TIMSS 2007 international science report: Findings from IEA's Trends in International Mathematics and Science Study at the fourth and eighth grades*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Martin, M.O., Mullis, I.V.S., Foy, P., & Stanco, G.M. (2012). *TIMSS 2011International results in science.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Martin, R.A., Puhlik-Doris, P., Larsen, G., Gray, J., & Weir, K. (2003). Individual differences in uses of humor and their relation to psychological well-being: Development of the humor styles questionnaire. *Journal of Research in Personality, 37,* 48-75.

Martin, R., Sexton, C. & Franklin, T. (2009). *Teaching science for all children: Inquiry methods for instructing understanding* (4th ed.). Boston, MA: Pearson Education.

Maskill, R. (1988). Logical language, natural strategies and the teaching of science. *International Journal of Science Education, 10*(5), 485-495.

Masters, G. (2006). *Boosting science learning - the challenge*. Paper presented at the ACER Research Conference: Boosting Science Learning -What will it take?, Retrieved from http://www.acer.edu.au/research_conferences/2006.html

Masson, J. (2002). Researching children's perspectives: Legal issues. In A. Lewis & G. Lindsay (Eds.), *Researching Children's Perspectives* (pp. 4-20). Buckingham, England: Open University Press.

Maykut, P., & Morehouse, R. (1994). *Beginning qualitative research: A philosophic and practical guide.* London, England: Routledge Falmer.

Meador, K.S. (2003). Thinking creatively about science. *Gifted Child Today, 26*(1), 25-29.

Mercer, N. (2004). Sociocultural discourse analysis: Analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics, 1*(2), 137-168.

Mercer, N. (2008). Talk and the development of reasoning and understanding. *Human Development, 51,* 90-100.

Merkens, H. (2004). Selection procedures, sampling, case construction. In U. Flick, E. von Kardoff and I. Steinke (Eds.) *A companion to qualitative research* (pp. 165-177). London, England: Sage.

Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, *22*(2), 219-290.

Meyerson, M., Ford, M., Jones, W., & Ward, M. (1991). Science vocabulary knowledge of third and fifth grade students. *Science Education, 75*(4), 419-428.

Milne, I. (2001). *What does this word 'material' mean?* Paper presented at Second Annual Science Education Symposium. University of Waikato, Hamilton, New Zealand.

Milne, C., & Otieno, T. (2007). Understanding engagement: Science demonstrations and emotional energy. *Science Education, 91*(4), 523-553.

Ministry of Business, Innovation and Employment. (2014). *A nation of curious minds: He whenua hihiri i te mahara. A national strategic plan for science in society.* Retrieved from www.mbie.govt.nz/info-services/science-innovation/curious-minds/

Ministry of Education. (2002). *Curriculum, learning and effective pedagogy: A literature review in science education*. Wellington, New Zealand: Ministry of Education.

Ministry of Education. (2007). *The New Zealand Curriculum.* Wellington, New Zealand: Learning Media.

Ministry of Education (2009a). *A focus on science achievement and engagement.* Wellington, New Zealand: Ministry of Education.

Ministry of Education. (2009b). *Ka Hikitia Managing for Success: The Māori Education Strategy 2008-2012.* Wellington, New Zealand: Ministry of Education.

Ministry of Education. (2009c). *Mathematics standards for years 1-8.* Wellington, New Zealand: Learning Media.

Ministry of Education. (2009d). *Reading and writing standards for years 1-8.* Wellington, New Zealand: Learning Media.

Ministry of Education. (2011). *Tātaiako: Cultural competencies for teachers of Māori learners.* Wellington, New Zealand: Ministry of Education.

Ministry of Education. (2013a). *Ka Hikitia: Accelerating success 2013-2017.* Wellington, New Zealand: Ministry of Education.

Ministry of Education. (2013b). *National Monitoring Study of Student Achievement: Science 2012.* Dunedin, New Zealand: Educational Assessment Research Unit.

Ministry of Education. (2014). *Ministry of Education Statement of Intent 2014-2018.* Wellington, New Zealand: Ministry of Education.

Ministry of Research, Science and Technology (MoRST). (2010). *Statement of intent: 2010/11.* Retrieved from: http://www.morst.govt.nz/publications/corporate-reports/soi/SoI-2010-2011/.

Misiti,F., Shrigley, R., & Hanson, L. (1991). Science attitude scales for middle school students. *Science Education, 75*(5), 525-540.

Moje, E., Collazo, T., Carrillo, R., & Marx, R. (2001). ‘‘Maestro, what is ‘quality’?’’: Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching, 38*, 469-498.

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly*, *39*(1), 38-70.

Molefe, L., & Stears, M. (2014). Rhetoric and reality: Science teacher educators' views and practice regarding science process skills. *African Journal of Research in Mathematics, Science and Technology Education, 18*(3), 219-230.

Monhardt, L., & Monhardt, R. (2006). Creating a context for the learning of science process skills through picture books. *Early Childhood Education Journal, 34*(1), 67-71.

Morgan, M., Gibbs, S., Maxwell, K., & Britten, N. (2002). Hearing children’s voices: Methodological issues in conducting focus groups with children aged 7-11 years. *Qualitative Research, 2*(1), 5-20.

Morgan, D.L., & Krueger, R. (1993). When to use focus groups and why. In D.L. Morgan (Ed.), *Successful focus groups: Advancing the state of the art* (pp. 3-19). Newbury Park, CA: Sage Publication.

Morrell, P. & Lederman, N.G. (1998). Students’ attitudes toward school and classroom science: Are they independent phenomena? *School Science and Mathematics, 98*(2), 76-83.

Morse, J.M., & Richards, L. (2002). *Read me first for a user’s guide to qualitative methods*. London, England: Sage.

Moustakas, C. (1994). *Phenomenological research methods.* Thousand Oaks, CA: Sage.

Munford, R., & Sanders, J. (2004). Recruiting diverse groups of young people to research. *Qualitative Social Work, 3,* 469-482.

Murcia, K. (2013). Secondary school students’ attitudes to nanotechnology. *Teaching Science, 59*(3), 15-21.

Murphy, C., & Beggs, J. (2001). Children’s perceptions of school science. *School Science Review, 84*(308), 109-116.

Murphy, C. & Beggs, J. (2003). Pupils’ attitudes, perceptions and understanding of primary science: Comparisons between Northern Irish and English schools. Paper presented at the Annual Meeting of the British Educational Research Association, Leeds, England, 14-16 September.

Murphy, C., & Beggs, J. (2005). *Primary science in the UK: A scoping study*. *Final Report to the Wellcome Trust.* London, England: Wellcome Trust.

Murphy, C., Bianchi, L., McCullagh, J., & Kerr, K. (2013). Scaling up higher order thinking skills and personal capabilities in primary science: Theory-into-policy-into - practice. *Thinking Skills and Creativity, 10,* 173-188.

Murphy, C., Neil, P., & Beggs, J. (2007). Primary science teacher confidence revisited: Ten years on. *Educational Research, 49*(4), 415-430.

Newton, D.P., & Newton, L.D. (2011). Engaging science: Pre-service primary school teachers' notions of engaging science lessons. *International Journal of Science and Mathematics Education, 9*(2), 327-345.

New Zealand Teachers Council. (2010). *Registered teacher criteria handbook.* Wellington, New Zealand: New Zealand Teachers Council.

Nieto, S. (2000). *Affirming diversity: The sociopolitical context of multicultural education* (3rd ed.). White Plains, NY: Longman.

Ng, W. (2010). Jelly making: Children's science discourse and thinking. *Teaching Science, 56*(3), 13-15.

Noddings, N. (2005). *Challenge to care in schools: An alternative approach to education teachers.* New York, NY: College Press, Teachers College, Columbia University.

Nuthall, G. (2007). *The hidden lives of learners.* Wellington, New Zealand: NZCER.

Office of the Chief Scientist. (2012). *Mathematics, engineering and science in the national interest.* Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/Office-of-the-Chief-Scientist-MES-Report-8-May-2012pdf

Olander, C., & Ingerman, A. (2011). Towards an inter-language of talking science: Exploring students' argumentation in relation to authentic language. *Journal of Biological Education, 45*(30), 158-164.

Olitsky, S., & Milne, C. (2012). Understanding engagement in science education: The psychological and the social. In B.J. Fraser, K. Tobin & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 19-34). Dordrecht, Netherlands: Springer.

Olsson, H., Backe, H., Sörensen, S., & Koch, M. (2002). The essence of humor and its effects and functions: A qualitative study. *Journal of Nursing Management, 10*(1), 21-

26.

Organisation for Economic Cooperation and Development. (2000). *Science, technology and innovation in the new economy.* Retrieved from www. oecd.org/science/sci-tech/1918259.pdf

Organisation for Economic Cooperation and Development. (2007). *PISA 2006 science competencies for tomorrow's world.* Paris: OECD.

Orr, K. (2013). Grantee Voice: Katy Orr - Taking chemistry out of the laboratory. Retrieved from www.fulbright.org.nz/newspublications/newsletters/february2013/katyorr/

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(23), 463-466.

Osborne, J., & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: A focus group study. *International Journal of Science Education, 23*(5), 441-467.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. A report to the Nuffield Foundation. London, England: Kings College.

Osborne, J. & Hennessy, S. (2003). *Literature review in science education and role of ICT: Promise, problems and future directions.* Futurelab Series, Report 6. Retrieved from http://www,futurelab.org.uk/resources/publications-reports-articles/literature-reviews/Literature-Reviews380.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education 25*(9), 1049-1079.

Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science.* Auckland, New Zealand: Heinemann.

Østergaard, E., Dahlin, B., & Hugo, A (2008). Doing phenomenology in science education: A research review. *Studies in Science Education, 44*(2), 93-121.

Ostlund, K. (1998). What the research says about science process skills: How can teaching process skills improve student performance in reading, language, arts and mathematics? *Electronic Journal of Science Education, 2*(4), 1-8.

Özgelen, S. (2012). Students' science process skills within a cognitive domain framework. *Eurasia Journal of Mathematics, Science and Technology Education, 8*(4), 283-292.

Öztürk, N., Tezel, O., & Acat, M.B. (2010). Science process skills levels of primary school seventh grade students in science and technology lesson. *Journal of Turkish Science Education 7*(3), 15-28.

Padilla, M. (1990). *The science process skills.* Retrieved from http://www.narst.org/publications/research/skill.cfm

Palmer, P. J. (1998). *The courage to teach: Exploring the inner landscape of a teacher's life*. San Francisco, CA: Jossey-Bass.

Palmer, D. (2007). What is the best way to motivate students in science? *Teaching Science, 53*(1), 38-42.

Panizzon, D. (2012). Science education in rural settings: Exploring the 'state of play' internationally. In B.J. Fraser, K. Tobin & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 527-539). Dordrecht, Netherlands: Springer. DOI 10.1007/978-1-4020-9041-7_36

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Peacock, D. (2007). Foreword. In R. Tytler, *Re-Imagining science education: Engaging students in science for Australia's future* (pp.iii-vi). Camberwell, Australia: Australian Council for Educational Research (ACER).

Pell, T., & Jarvis, T. (2001). Developing attitude to science scales with children of ages from five to eleven years. *International Journal of Science Education, 2*(8), 847-862.

Penrice, G. (2011). The effects of intensification on rural teachers' work. *New Zealand Journal of Teachers' Work, 8*(2), 104-113.

Penrice, G. (2012). Accountability: Rural teachers and their work. *New Zealand Journal of Educational Studies, 47*(1), 79-91.

Penrice, G., & Sexton, S. (2012). *Discourses of rural primary school science.* Proceedings of the New Zealand Association of Science Educators (NZASE)Science Conference (SciCon): Making Connections. Retrieved from http://www.scicon2012.org.nz

Penrice, G., & Sexton, S. (2013). Engaging primary students through science action research. *New Zealand Science Teacher, 132,* 59-61.

Peterson, S.M., & French, L. (2008). Supporting young children's explanations through inquiry science in preschool. *Early Childhood Research Quarterly, 23,* 395-408.

Peterson, P.L., Swing, S.R., Stark, K.D., & Waas, G.A. (1984). Students' cognitions and time on task during mathematics instruction. *American Educational Research Journal,* *21*(3), 487–515.

Petty, R.E. (2012). Attitude change. In V.S. Ramachandran (Ed.), *Encyclopedia of human behaviour* (2nd ed., pp. 224 -229). Boston, MA: Elsevier.
Piburn, M., & Baker, D. (1993). If I were the teacher: Qualitative study of attitude towards science. *Science Education, 77*(4), 393-406.

Pickens, M., & Eick, C. (2009). Studying motivational strategies used by two teachers in differently tracked science courses. *The Journal of Educational Research, 102*(5), 349-362.

Pickering, A. (1995). *The mangle of practice: Time, agency and science*. Chicago, IL: University of Chicago Press.

Pickersgill, S., & Lock, R. (1991). Student understanding of selected non-technical words in science. *Research in Science and Technological Education, 9*(1), 71-79.

Poland, B. D. (2001). Transcription quality. In J.F. Gubrium & J.A. Holstein (Eds.), *Handbook of Interview Research* (pp. 629-650). London, England: Sage.

Pole, C., Mizen, P., & Bolton, A. (1999). Realising children's agency in research: Partners of participants? *International Journal of Social Research Methodology, 2*(1), 39-54.

Powell, M.A. & Smith, A.B. (2006). Ethical guidelines for research with children: A review of the current research ethics documentation in New Zealand. *Kotuitui: New Zealand Journal of Social Sciences Online, 1*(2), 125-138.

Powell, M.A., & Smith, A.B. (2009). Children's participation rights in research. *Childhood, 16*(1), 124-142.

Pring, R. (2000). The 'false dualism' of educational research. *Journal of Philosophy of Education, 34*(2), 247-260.

Prosser, J. (2011). Visual methodology: Toward a more seeing research. In N.K. Denzin & Y.S. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (pp. 479-496). Thousand Oaks, CA: Sage.

Punch, K.F. (2005). *Introduction to social research: Quantitative and qualitative approaches* (2nd ed). London, England: Sage Publications.

Punch, S. (2002b). Research with children: The same or different from research with adults? *Childhood, 9*(3), 321-341.

Qualter, A. (1993). I would like to know more about that: A study of the interest shown by girls and boys in scientific topics. *International Journal of Science Education, 15*(3), 307-317.

Rahm, J. (2003). Multiple modes of meaning-making in a science centre. *Science Education, 88,* 223-247.

Ramig, J.E., Bailer, J., & Ramsey, J.M. (1995). *Teaching science process skills.* U.S.A: McGraw-Hill.

Ramsden, J.M. (1998). Mission impossible?: Can anything be done about attitudes to science? *International Journal of Science Education, 20*(2), 125-137.

Ratcliffe, M., Hanley, P., & Osborne, J. F. (2007). *Evaluation of twenty first century science GCSE Strand 3: The teaching of twenty first century science GCSE, and teachers' and students' views of the course*. Southampton, England: University of Southampton.

Raved, l., & Assaraf, O.B.Z. (2011). Attitudes towards science learning among 10th grade students: A qualitative look. *International Journal of Science Education, 33*(9), 1219-1243.

Reid, N. (2006). Thoughts on attitude measurement. *Research in Science and Technological Education, 24*(1), 3-27.

Reschly, A., & Christenson, S. L. (2006a). Promoting successful school completion. In G. Bear & K. Minke (Eds.), *Children's needs—III: Development, prevention, and intervention* (pp. 103-113). Bethesda, MD: National Association of School Psychologists.

Reschly, A., & Christenson, S. L. (2006b). Research leading to a predictive model of dropout and completion among students with mild disabilities and the role of student engagement. *Remedial and Special Education, 27*, 276-292.

Reschly, A.L., & Christenson, S.L. (2012). Jingle, jangle and conceptual haziness: Evolution and future directions of the engagement construct. In S.L. Christenson, A.L. Reschly & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 3-19). Dordrecht, Netherlands: Springer.

Reznitskaya, A., & Gregory, M. (2013). Student thought and classroom language: Examining the mechanisms of change in dialogic teaching. *Educational Psychologist, 48*(2), 114-133.

Ritz, W.C. (Ed.). (2007). *A head start on science: Encouraging a sense of wonder.* Arlington, VA: National Science Teachers.

Roberts, P. (2014). Researching from the standpoint of the rural. In S. White & M. Corbett (Eds.). *Doing educational research in rural settings: methodological issues, international perspectives and practical solutions* (pp. 280-303). Hoboken, NJ: Taylor & Francis.

Roberts, R. (2001). Procedural understanding in biology: The 'thinking behind the doing.' *Journal of Biological Education, 35*(3), 113-117.
Rogers, R., Malancharuvil-Berkes, E., Mosley, M., Hui, D., & O'Garra Joseph, G. (2005). Critical discourse analysis in education: A review of the literature. *Review of Educational Research, 75*(3), 365-416.

Rogoff, B. (1994). Developing understanding of the idea of communities of learners. *Mind, Culture, and Activity, 1*(4), 209-229.

Roth, W-M. (2005a). *Doing qualitative research: Praxis of method.* Rotterdam, Netherlands: Sense.

Roth, W-M. (2005b). *Talking science: Language and learning in science classrooms.* Lanham, ML: Rowman & Littlefield.

Roth, W-M. (2005c). Telling in purposeful activity and the emergence of scientific language. In R.Yerrick & W-M. Roth (Eds.), *Establishing scientific classroom discourse Communities: Multiple voices of teaching and learning research* (pp. 45-72). Mahwah, NJ: Lawrence Erlbaum Associates.

Roth, W-M. (2008). The nature of scientific conceptions: A discursive psychological perspective. *Educational Research Review, 3,* 30-50.

Roth, W-M. (2014). Science language wanted alive*:* Through the dialectical/dialogical lens of Vygotsky and the Bakhtin Circle. *Journal of Research in Science Teaching, 51*(8), 1049-1083.

Roth, W-M., & Lucas, K. (1997). From "truth" to "invented reality": A discourse analysis of high school physics students' talk about scientific knowledge. *Journal of Research in Science Teaching, 34*, 145-179.

Rowell, P. M., & Ebbers, M. (2004). Shaping school science: Competing discourse in an inquiry-based elementary program. *International Journal of Science Education*, *26*(8), 915–934.

Rudduck, J., & Flutter, J. (2004). *How to improve your school: Giving pupils a voice*. London, England: Continuum.

Rumberger, R.W., & Rotermund, S. (2012). The relationship between engagement and high school dropout. In S.L. Christenson, A.L. Reschly & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 491-513). Dordrecht, Netherlands: Springer.

Saat, R.M. (2004). The acquisition of integrated process skills in a web-based learning environment. *Research in Science and Technological Education, 22*(1), 23-40.

Sadeh, I., & Zion, M. (2009). The development of dynamic inquiry performances within an open inquiry setting: A comparison to guided inquiry setting. *Journal of Research in Science Teaching*, *46*(10), 1137-1160.

Sadeh, I., & Zion, M. (2012). Which type of inquiry project do high school biology students prefer: Open or guided? *Research in Science Education, 42*, 831-848.

Samu, T.W. (2006). The 'Pasifika Umbrella' and quality teaching: Understanding and responding to the diverse realities within. *Waikato Journal of Education, 12,* 36-49.

Savage, C., Hindle, R., Meyer, L. H., Hynds, A., Penetito, W., & Sleeter, C.E. (2011) Culturally responsive pedagogies in the classroom: Indigenous student experiences across the curriculum. *Asia-Pacific Journal of Teacher Education, 39*(3), 183-198.

Schoultz, J., Saljo, R., & Wyndhamn, J. (2001). Heavenly talk: Discourse, artifacts, and children's understanding of elementary astronomy. *Human Development, 44,* 103-118.

Seale, C. (2005). Sampling in qualitative research. In S. Becker & A. Bryman (Eds.). *Understanding research for social policy and practice: Themes, methods and approaches* (pp. 261-267). Bristol, England: The Policy Press.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (3rd ed.). New York, NY: Teachers College Press.

Settlage, J., & Southerland, S. (2007). *Teaching science to every child: Using culture as a starting point.* New York, NY: Routledge.

Schagen, S. & Hipkins, R. (2008). *Curriculum changes, priorities, and issues: Findings from the NZCER secondary 2006 and primary 2007 national surveys.* Wellington, New Zealand: NZCER.

Shernoff, D.J., Csikszentmihalyi, M., Schneider, B., & Shernoff, E.S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly, 18*(2), 158-176.

Shrigley, R.L., Koballa, T.R., & Simpson, R.D. (1988). Defining attitude for science educators. *Journal of Research in Science Teaching, 25*(8), 657-678.

Simpson, R.D., & Oliver, J.S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74*(1), 1-18.

Simsek, P., & Kabapinar, F. (2010). The effects of inquiry-based learning in elementary students' conceptual understanding of matter, scientific process skills and science attitudes. *Procedia Social and Behavioural Sciences, 2*, 1190-1194.

Sinatra, G.M., Heddy, B.C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist, 50*(1), 1-13.

Siry, C., Ziegler, G., & Max, C. (2012). "Doing science" through discourse-in-interaction: Young children's science investigations at the early childhood level. *Science Education, 96*(2), 311-336.

Skamp, K. (2007). Conceptual learning in the primary and middle years: The interplay of heads, hearts and hands-on science. *Teaching Science, 53*(3), 18-22.

Skamp, K. (2015). Teaching primary science constructively. In K. Skamp & C. Preston (Eds.), *Teaching Primary Science Constructively* (5th ed., pp. 1-40). Victoria, Australia: Cengage Learning.

Skamp, K. & Logan, M. (2005). Students' interest in science across the middle school years. *Teaching Science, 51*(4), 8-15.

Skinner, E.A., & Belmont, M.J. (1993). Motivation in the classroom: Reciprocal effects of teacher behaviour and student engagement across the school year. *Journal of Educational Psychology, 85*(4), 571-581.

Skinner, E.A., Kindermann, T.A., & Furrer, C.J. (2009). A motivational perspective on engagement and disaffection: Conceptualization and assessment of children's behavioural and emotional participation in academic activities in the classroom. *Educational and Psychological Measurement, 69,* 493-525.

Skinner, E., Marchand, G., Furrer, C., & Kindermann, T. (2008). Engagement and disaffection in the classroom: Part of a larger motivational dynamic? *Journal of Educational Psychology, 100*(4), 765-781.

Sligo, J. (2001). *Childrens' Understandings about Success*. Unpublished Masters thesis, University of Otago, Dunedin, New Zealand.

Smith, M.K. (2012). "What is pedagogy?", The encyclopedia of informal education. Retrieved from http://infed.org/mobi/what-is-pedagogy/

Smetana L.K., & Bell, R.L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education, 34*(9), 1337-1370.

Snellman, K., Silva, J.M., Frederick, C.B., & Putnam, R.D. (2015). The engagement gap: Social mobility and extracurricular participation among American youth. *The ANNALS of the American Academy of Political and Social Science, 657*(1), 194-207.

Sobel, D. (2004). *Place-based education: Connecting classrooms and communities.* Great Barrington, MA: The Orion Society.

Southerland, S., Kittleson, J., Settlage, J., & Lanier, K. (2005). Individual and group meaning-making in an urban third grade classroom: Red fog, cold cans and seeping vapour. *Journal of Research in Science Teaching, 42*(9), 1032-1061.

Speering, W., & Rennie, L. (1996). Students' perceptions about science: The impact of transition from primary to secondary school. *Research in Science Teaching, 26*(3), 283-298.

Starks, H., & Trinidad, S. (2007). Choose your method: A comparison of phenomenology, discourse analysis and grounded theory. *Qualitative Health Research, 17*(10), 1372-1380.

Statistics New Zealand. (2004). *New Zealand: An urban/rural profile.* Statistics New Zealand. Retrieved from https://www.msd.govt.nz/

Stoddard, T., Pinal, A., Latze, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching, 39*(8), 664-687.

Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research* (2nd ed.). Thousand Oaks, CA: Sage.

Stieger, S., Formann, A.K., & Burger, C. (2011). Humor styles and their relationship to explicit and implicit self-esteem. *Personality and Individual Differences, 50*(5), 747-750.

Sullivan, F.R. (2008). Robotics and science literacy: Thinking skills , science process skills and systems understanding. *Journal of Research in Science Teaching, 45*(3), 373-394.

Sutton, C. (1998). New perspectives on language in science. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (Vol 1, pp.27-38). Dordrecht, Netherlands: Kluwer Academic.

Swarat, S., Ortony, A., & Revelle, W. (2012). Understanding matters: Understanding student interest in school science. *Journal of Research in Science Teaching, 49*(4), 515-537.

Taconis, R. & Kessels, U. (2009). How choosing science depends on students' individual fit to 'science culture'. *International Journal of Science Education, 31*(8), 1115-1132.

Tai, R.H., Liu, C.Q., Maltese, A.V., & Fan, X. (2006). Planning early for careers in science. *Science, 312,* 1143-1145.

Tate, P. M. (2007). Academic and relational responsibilities of teaching. *Journal of Education, 187*(3), 1-20.

Taylor, R. (2014) Meaning between, in and around words, gestures and postures: Multimodal meaning-making in children's classroom discourse. *Language and Education, 28*(5), 401-420

Taylor, S.J. & Bogdan, R. (1998). *Introduction to qualitative research methods* (3rd ed.). New York, NY: John Wiley.

Te Whāiti, P., & McCarthy, M.B. (1997). *Mai i Rangiaatea: Māori wellbeing and development.* Auckland, New Zealand: Auckland University Press.

Tek, O.E., & Ruthven, K. (2005). Acquisition of science process skills amongst Form 3 students in Malaysian Smart and Mainstream Schools. *Journal of Science and Mathematics in S.E.Asia, 28*(1),103-124.

Toplis, R. (2011). Students' views about secondary school science lessons: The role of practical work. *Research in Science Education, 42,* 531-549.

Treeby, B., & Burtenshaw, M. (2003). *Comparative study on rural education and rural enterprises development: New Zealand country report and case study.* Retrieved from http://www.openpolytechnic.ac.nz/

Tschannen-Moran, M., & Hoy, W.K. (2000). A multidisciplinary analysis of the nature, meaning, and measurement of trust. *Review of Educational Research, 70*(4) 547-593.

Turpin, T. & Cage, B.N. (2004). The effects of an integrated, activity-based science curriculum on student achievement, science process skills and science attitudes. *Electronic Journal of Literacy through Science, 3,* 1-17.

Tytler, R. (2003). A window for a purpose: Developing a framework for describing effective science teaching and learning. *Research in Science Education, 33*(3), 273-298.

Tytler, R. (2007). *Re-imagining science education: Engaging students in science for Australia's future.* Melbourne, Australia: Australian Council for Educational Research.

Tytler, R., & Aranda, G. (2015). Expert teachers' discursive moves in science classroom interactive talk. *International Journal of Science and Mathematics Education, 13*(2), 425-446.

Tytler, R., Osborne, J., Williams, G., Tytler, K., & Cripps Clark (2008). *Opening up pathways: Engagement in STEM across the primary–secondary school transition:* A review of the literature concerning supports and barriers to science, technology, engineering and mathematics engagement at primary–secondary transition. Canberra, ACT: Department of Education, Employment and Workplace Relations. Retrieved from http://trove.nla.gov.au/work/26811699?selectedversion=NBD43493850

Uekawa, K., Borman, K., & Lee, R. (2007). Student engagement in U.S. urban high school mathematics and science classrooms: Findings on social organization, race, and ethnicity. *The Urban Review, 39*(1), 1-43.

van Aaldered-Smeets, S., van der Molen, J., & Asma, L. (2012). *Science Education, 96*(1), 158-182.

Vandenberg, D. (2002). Phenomenology and Fundamental Educational Theory. In A. Tymieniecka, (Ed.), *Phenomenology world-wide. Foundations – expanding dynamics - life-engagements: A guide for research and study* (pp. 589-600). Dordrecht, Netherlands: Kluwer Academic Publishers.

van Manen, M. (1990). *Researching lived experience: Human science for an action sensitive pedagogy.* Ontario, Canada: The Althouse Press.

van Manen, M. (1991a). Reflectivity and the pedagogical moment: The normativity of pedagogical thinking and acting. *Journal of Curriculum Studies, 23*(6), 507-536.

van Manen, M. (1991b). *The tact of teaching: The meaning of pedagogical thoughtfulness.* Ontario, Canada: The Althouse Press.

van Manen, M. (1999). The language of pedagogy and the primacy of student experience. In J. Loughran (ed.). *Researching teaching: Methodologies and practices for understanding pedagogy* (pp. 13-27). London, England: Falmer Press.

van Manen, M. (2007). *Researching lived experience: Human science for an action sensitive pedagogy* (2nd ed.). Ontario, Canada: The Althouse Press.

Varelas, M., Pappas, C., Barry, A., & O'Neill, A. (2001). Examining language to capture scientific understandings: The case of the water cycle. *Science and Children, 38*(7), 26-29.

Varelas, M., Pappas, C., Kane, J.M., & Aresnault, A. (2008). Urban primary-grade children think and talk science: Curricular and instructional practices that nuture participation and argumentation. *Science Education, 92*(1), 65-95.

Varelas, M., Pappas, C., & Rife, A. (2006). Exploring the role of intertextuality in concept construction: Urban second graders make sense of evaporation, boiling, and condensation. *Journal of Research in Science Teaching, 43*(7), 637-666.

Varelas, M., Pieper, L., Arsenault, A., Pappas, C., Keblawe-Shamah, N. (2014). How science texts and hands-on explorations facilitate meaning-making: Learning from Latina/o graders. *Journal of Research in Science Teaching, 51*(10), 1246-1274.

Varley, J., Murphy, C., & Veale, Ó. (2008). *Science in Primary Schools: Phase 1 Final Report.* National Council for Curriculum and Assessment. Retrieved from http://www.ncca.ie/uploadedfiles/primary/Binder1.pdf.

Vygotsky, L. (1981). *Thought and language* (Rev. ed.). A. Kozulin (Ed.). Cambridge, MA: MIT Press.

Wallace, C. S. (2004). Framing new research in science literacy and language use: Authenticity, multiple discourse, and the "third space." *Science Education, 88*(6), 901-914.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A.S., & Hudicourt-Barnes. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38*(5), 529-552.

Wellington, J. (1998). *Practical Work in School Science. Which Way Now?* London, England: Routledge.

Wellington, J. & Osborne, J. (2001). *Language and literacy in science education.* Buckingham, England: Open University Press.

Wells, G. (1999). *Dialogic Enquiry: Towards a sociocultural practice and theory of education*. Cambridge, England: Cambridge University Press.

Wenham, M. (2005). *Understanding primary science: Ideas, concepts and explanations* (2nd ed.). London, England: Paul Chapman Publishing.

Wenham, M., & Ovens, P. (2010) *Understanding primary science: Science knowledge for teaching* (3rd ed.). London, England: Sage Publications.

Whitten, M., Tuck, B., & Haig, M. (2003). *Investigating student attitudes to science before and after transition from primary school to secondary school.* Paper presented at the 34th annual conference of the Australasian Science Education Research Association, Melbourne, Australia.

Wigfield, A., Guthrie, J.T., Perencevich, K.C., Yaboada, A., Klauda, S.L., McRae, A., & Barbosa, P. (2008). Role of reading engagement in mediating effects of reading comprehension instruction on reading outcomes. *Psychology in the Schools, 45*(5), 432-445.

Wilkinson, I.A.G., Parr J.M., Fung, I.Y.Y., Hattie, J.A.C., & Townsend, M.A.R. (2002). Discussion: Modeling and maximizing peer effects in school. *International Journal of Educational Research, 37*(5), 521-535.

Williams, N.M., & Broadley, M. (2012). *Resource kit for student teachers.* Ako Aotearoa Wellington, New Zealand: National Centre for Tertiary Teaching Excellence.

Williams, D., Ma, Y., Prejean, L., Ford, M., & Lai, G. (2007). Acquisition of physics content knowledge and scientific inquiry skills in a robotics summer camp. *Journal of Research on Technology in Education, 40*(2), 201-216.

Wilson, T. D., Lindset, S., & Schooler, T. Y (2000). A model of dual attitudes. *Psychology Review, 107,* 101-126.

Woodruff, E., & Meyer, K. (1997). Explanations from intra- and inter-group discourse: Students building knowledge in the science classroom. *Research in Science Education, 27*(1), 25-39.

Wray, D. & Lewis, M. (1997). *Extending Literacy: Children reading and writing non-fiction*. London, England: Routledge.

Wright, A. (2012). *Creating and sustaining an "effective" rural school: The critical triad - leadership, curriculum, and community.* Unpublished Doctoral dissertation, University of Otago, Dunedin, New Zealand.

Wu, H-K., & Hsieh, C-E. (2006). Developing sixth graders' inquiry skills to construct explanations in inquiry-based learning environments. *International Journal of Science Education, 28*(11), 1289-1313.

Wu, H-K., & Krajcik, J.S. (2006). Inscriptional practices in two inquiry-based classrooms: A case study of seventh graders' use of data tables and graphs. *Journal of Research in Science Teaching, 43*(1), 63-95.

Wylie, C. & Hipkins, R. (2006). *Growing Independence: Competent Learners@14.* Wellington, New Zealand: New Zealand Council for Educational Research.

Wylie, C., Hipkins, R., & Hogden, E. (2008). *On the Edge of Adulthood: Young people's school and out-of-school experiences at 16.* Wellington, New Zealand: New Zealand Council for Educational Research.

Wylie, C., & Hodgen, E. (2012). Trajectories and patterns of student engagement: Evidence from a longitudinal study. In S.L. Christenson, A.L. Reschly & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 585-599). Dordrecht, Netherlands: Springer.

Yager, R.E., & Akcay, H. (2010). The advantages of an inquiry approach for science instruction in middle grades. *School Science and Mathematics, 110*(1), 5-12.

Yair, G. (2000). Reforming motivation: How the structure of instruction affects students' learning experiences. *British Educational Research Journal, 26*(20), 191-210.

Young, K., & Talaquer, V. (2013). Effect of different types of small-group activities on students' conversations. *Journal of Chemical , 90,* 1123-1129.

Yusoff, R., & Janor, R.M. (2014). Generation of an interval metric scale to measure attitude. *SAGE Open,4* (1), 1-16.

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review, 27,* 172-223.

Ziv, A. (1984). *Personality and sense of humor.* New York, NY: Springer

APPENDIX A: CHEMISTRY OUTREACH PROGRAMME
Phase One: Introductory sessions September - December 2011 (6 half day sessions) **Focus:** The 'wow' factor in science
Aim: To engage and motivate students in variety of teacher demonstrations and pre-determined hands-on activities designed to engage the students in the 'wow' factor. **Content:** A range of experiments to show changes in the 3 states of matter using liquid nitrogen and dry ice - liquid nitrogen to freeze everyday objects such as rubber tubing, mandarins, onions; dry ice placed inside a balloon to inflate the balloon. Activities emphasizing the skills of measuring accurately, reporting observations, and replication Pedagogical Format: Structured inquiry - Teacher demonstration for changes in 3 states of matter activities. Student selected partners for hands on skills activities **Extra Social Interactions:** Barbeque and cricket match between Chemistry Outreach team and students (November 2011) Whole school session plus parents and pre-schoolers dancing in liquid nitrogen fog and making fizzy drinks using dry ice (December 2011)
Phase Two: pH activities February 2012-May 2012 (6 half day sessions) **Focus:** Shift the control from teacher to students with science activities that make connections with science and the students' lives through student generated ideas of interest areas.
Aim: To involve students more in the preparation, planning and doing of the activities **Content:** Making natural pH indicator by extracting anthocyanin from red cabbage to test pH of everyday substances; pH scale including safety of liquids in relation to acidity and alkalinity readings; making green eggs; using red cabbage indicator and universal pH indicator to testing pH of food in lunch boxes; testing, collating, and comparing pH of water and soil samples collected from school and farm environments **Pedagogical Format:** Guided Inquiry-Scaffolded Learning Experiences Student selected partners **Extra Social Interactions**: Students visited the Chemistry Outreach team at University of Otago for activities in the science laboratory. This occurred on the way home from the class camp and most parents of these children attended as well. (March 2012)
Phase Three: Student Directed Investigations July-December 2012 (8 half day sessions) **Focus:** Student ownership of choice, planning, design, conduct and evaluation of student driven scientific investigation in their rural community
Aim: To involve the students in using newly acquired skills of water and soil pH testing to plan, design, conduct and evaluate scientific investigations in their community **Content**: Scientific inquiry design. Student choice of investigation; teaching of sampling, analysis and recording skills; students conducting investigation and presentation of their research investigation to local community at end of year assembly **Pedagogical Format**: Open inquiry: Problem solving in authentic learning contexts. Student selected groups of 3 students **Extra Social Interactions**: Students were finalists in Department of Conservation Schools Toroa Award 2012. Several of the Outreach team assisted with presentation and attended the ceremony with the student representatives (October, 2012). The Chemistry Outreach team were invited to Community End of Year Assembly. They presented awards and did the lighting of hands on fire activity with the students and parents (December, 2012).

APPENDIX B		
CHEMISTRY OUTREACH PROGRAMME	**DATA COLLECTION SCHEDULE**	
Phase	**Data Gathering** **Dimensions examined**	**Rationale**
Pre-programme: July - August 2011	**Focus Group Interviews 1** **Attitude; skills; language**	To elicit students' attitude towards science education, students' self-reports of scientific skills usage, students' use of scientific language in their oral recounts of school science experiences prior to the students experiencing the Chemistry Outreach programme
	Jelly Crystal Investigations (teacher selected groups) Engagement; skills; language	To observe task engagement, scientific skills and use of scientific language in a student to student social context prior to the students experiencing the Chemistry Outreach programme
Phase One: Introductory sessions September - December 2011		
Phase Two: pH activities February 2012-June 2012	**Focus Group Interviews 2** June Attitude	To elicit students' attitude towards science education, and ideas about the relevancy of science in their parents' everyday life
	Book Covers during phase 2 (individual) Attitude	To establish students' attitudes towards the Chemistry Outreach programme through the comments the students wrote on their Chemistry Outreach science book covers
Phase Three: **Student directed Investigations** July- December 2012	**Magnesium Investigations** (student selected groups) July Engagement; skills; language	To observe task engagement, scientific skills and use of scientific language in a student to student social context to compare with the pre-programme jelly crystal investigation to establish changes over time
	Reflective Writing December (individual) Attitude	To establish students' attitude towards the Chemistry Outreach programme and any changes over time
Post- programme: February 2013-April 2013	**Focus Group Interviews 3** Attitude; engagement; skills; language	To elicit students' possible intentions concerning long-term engagement with science To encourage students to compare the Chemistry Outreach programme with their experiences with other school science programmes To elicit students' attitude towards science education, students' self-reports of scientific skills usage, students' use of scientific language in their oral recounts of school science experiences for comparison with pre-programme interviews
	Parents and Community Members Interviews Culture (see Section 7.3.1)	To elicit adults' views of the culture of the community studied in this research

APPENDIX C: Interview Schedule for Students	
Interview Question	**Purpose of Interview Question**
Who can tell me about what they think about science? Focus Group 1,2,3	To encourage the students to elaborate on what they think science is
What have you done in science at school? Focus Group 1,3	To establish students' use of scientific language in their oral recounts of school science experiences
What do you think you are good at in science? Focus Group 1,3	To elicit students' self-reports of scientific skills usage
Why do we learn about science at school? Focus Group 1	To establish how important students view science as a learning area and the relevance of science education as a possible indicator of long-term engagement with science
How can science at school help you when you grow up? How do your parents use the science they learnt at school? Focus Group 1,2	To establish how relevant students see science in their future lives, as a possible indicator of long term engagement with science
Will you take science at secondary school? Focus Group 3	To establish students' possible intentions concerning long-term engagement with science
How do you feel about the Chemistry Outreach science programme? What have you got out of doing science with the Chemistry Outreach team? Is Chemistry Outreach different from the science you used to do? If so, how is it different? Focus Group 3	Elicit students' attitudes towards the Chemistry Outreach programme and any changes over time Comparison of Outreach Science programme with other school science programmes
Is there anything else that you can think of that I haven't asked you about the Chemistry Outreach programme that you would like to share? Focus Group 3	The opportunity to provide supplementary information the student regard as being important about the Chemistry Outreach programme.

Appendix D

Trend Task: Jelly Crystals

Approach: Team

Focus: Design a fair test experiment into the dissolving rates of jelly crystals

Resources: Jelly crystals, jug of hot water, jug of cold water, 2 plastic glasses, 2 teaspoons, recording sheet, stopwatch

Year: 4 & 8

Questions / instructions:

Preparation: Jug of hot water.

Don't hand out equipment yet.

This activity involves testing jelly crystals. In your team you will design a test to find out if jelly crystals dissolve faster in hot or cold water. You will need to do a fair test. In a fair test, only one important thing is changed at a time (for example, the temperature of water).

In your team think about how you will do your test. Here is some equipment you will be able to use. When you have decided on how to do the test I will ask you to tell me what you will do.

Hand out equipment. Allow time.

1. Tell me how you will do the test so that it is a fair test.

   Record team response.

Plan:	% response 2007 ('03) year 4	year 8
same amount of water	29 (38)	78 (91)
same amount of jelly crystals	49 (72)	84 (98)
start timing for both as soon as water or jelly crystals are added	36 (41)	65 (59)
emphasis on treating both alike (e.g. stir both at same speed and intensity)	24 (34)	61 (55)
careful observation and timing of when dissolving is complete	40 (44)	57 (53)

2. How will you know which one dissolves fastest?

	year 4	year 8
compare the times it takes to dissolve all jelly crystals	42 (51)	53 (74)

3. How is your test a fair test? You explain it to me and I will write it down to help you during your test.

   Record team response.

	year 4	year 8
not marked	•	•

You can now do your experiment. After you have done the test, you will tell me what you found out.

Actual experiment:	% response 2007 ('03) year 4	year 8
used same amount of water	63 (64)	86 (98)
used same amount of jelly crystals	71 (83)	94 (94)
started timing for both as soon as jelly crystals or water added	48 (62)	75 (80)
emphasis on treating both alike (e.g. stir both at same speed and intensity)	32 (35)	63 (57)
watched carefully for dissolving to be completed/timed accordingly	75 (65)	91 (89)
compared specific times it took to dissolve	22 (31)	39 (45)

4. Do jelly crystals dissolve faster in hot or cold water?

	year 4	year 8
hot	88 (92)	100 (100)

5. What else did you find out?
6. Now I want you to look at what you told me you would do to make sure it was a fair test. Is that what you did?
7. Tell me about how that part went.

Retrospective evaluation: *(suggested corrections)*

	year 4	year 8
same amount of water	9 (13)	11 (8)
same amount of jelly crystals	3 (3)	6 (2)
start timing for both as soon as water or jelly crystals are added	8 (8)	10 (17)
emphasis on treating both alike (e.g. stir both at same speed and intensity)	9 (13)	31 (46)
careful observation and timing of when dissolving is complete	14 (4)	5 (15)
compare specific times it takes to dissolve	6 (4)	6 (6)

Participation in planning, experiment and discussion:

	year 4	year 8
all students participated	84 (70)	81 (83)
all except one student participated	13 (26)	17 (15)
half of the students participated	3 (4)	2 (2)
less than half of the students participated	0 (0)	0 (0)

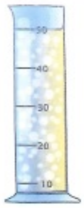
Total score:	year 4	year 8
12–18	4 (10)	17 (22)
10–11	13 (7)	36 (50)
8–9	17 (30)	33 (21)
6–7	26 (33)	13 (7)
0–5	40 (20)	1 (0)

Commentary:

Because this is a team task, no graph of subgroup performance is possible. Year 8 teams generally showed much stronger understanding of fair testing requirements. At both year levels, but especially year 4, there was a marked decline in performance between 2003 and 2007.

Lesson 2: Mixing of Particles

Appendix E



Measure 50 mL of HCl acid in a measuring cylinder.

1

Pour HCl into conical flask.

2

Add 2 cm of Magnesium ribbion.

3

Record the time it takes for the Magnesium to disappear.

4

X3

Repeat the experiment three times and calculate an average time.

5

Repeat the experiment with 40 mL HCl + 10 mL water, and 30 mL HCl + 20 mL water.

6

	1 (s)	2 (s)	3 (s)	Average (s)
50 mL HCl				
40 mL HCl + 10 mL water				
30 mL HCl + 20 mL water				

What happened as you added more water?

What is the water doing?

Chemistry Outreach

APPENDIX F: Participant's Significant Statements	Meaning units	Major themes
	The students trusted the scientists because the scientists' knowledge and experience meant they were more credible	**Interpersonal Connectedness (Trust)**
I trust them more [than teachers] because they've had the practice before they come here and do it (Tom, FG2).	Knowledgeable/ experienced - trust the scientists because they are more expert than teachers	
They've had all that training at university (Peter, FG3).	Knowledgeable/ experienced - university training	
They go to university and do experiments everyday (Lisa, FG2).	Knowledgeable/ experienced - university training	
They've been learning science for five or six years (Peter, FG3)	Knowledgeable/ experienced – time spent doing science	
They know more than Dave (Jerry, FG3).	Degree of expertise - more expert than Dave	
They can do things that other people can't (Ken, FG3).	Degree of expertise - do things others can't	
They can explain all what it means and how to do it properly… they're professionals… and they're experts. They know exactly what to do and why to do it (Maree, FG2).	Knowledgeable - able to explain how and why to do it	
They can tell you exactly what to do and why you have to do it.	Knowledgeable - able to explain how and why to do it	
They know how to do everything and they've done it before so nothing bad will happen (John, FG3).	Knowledgeable and experienced so things won't go wrong	
They explain it better because they do it more precisely because they know what they are talking about (Maree, FG3)	Knowledgeable - able to explain better	
Like we trusted them. When we're putting the bubbles on, and lighting them on fire I knew it was safe 'cause…scientists wouldn't lie about…Yeah 'cause they wouldn't light you fire on purpose…and I know I	Belief the scientists wouldn't lie or let you do anything that was dangerous	

can trust them, 'cause he did it first to show us that it was that it was safe. (Peter, FG3) They know more (Tom, FG3)	Demonstrations indicated to students that scientists were willing to do it so must be safe Knowledgeable	
   They were like being really nice tous, and they'd let us have a go at it, even though it us be a little dangerous (Tom, FG3) Because they do things, 'cause they can trust us 'cause we're older now, so we can do things with chemicals and we know not to eat anything, or put anything, unless we are told we're allowed. We can do it ourselves (Lisa, FG3) They let us actually do the experiment instead of just telling us (Kelly, FG3) In the junior room the teacher was putting all the stuff in because we weren't that careful but now that we're careful in the senior rom the scientists let us do what we're doing (Peter, FG3) Mmm, they're really nice and if you muck up they don't tell you off or anything. They just say, oh we could do it again. And they have enough tools to do it twice if we need too if we muck up (Abby FG3)	**The students perceived the scientists trusted them.** The scientists let the students participate in what the students perceived to be dangerous activities Scientists let the students do the science activities because the students will follow instructions Scientists trusted the students to follow instructions Scientists appreciated the students will be careful when engaging in science activities Scientists appreciated the students may make mistakes as part of their learning	**Interpersonal Connectedness (Reciprocal Trust)**

APPENDIX G1

Discourses of Rural Primary School Science

CONSENT FORM FOR PARENTS/GUARDIANS OF PARTICIPANTS UNDER 18 YEARS OF AGE

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.
I know that:-

1. My child's participation in the project is entirely voluntary;

2. I am free to withdraw my child from the project at any time without any disadvantage;

3. Personal identifying information [video-tapes] will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for five years, after which they will be destroyed;

4. This project involves a semi-structured questioning technique. The general line of questioning includes how my child sees science and its relevance to their world. The precise nature of the questions which will be asked have not been determined in advance, but will depend on the way in which the interview develops and that in the event that the line of questioning develops in such a way that my child feels hesitant or uncomfortable he/she may decline to answer any particular question(s) and/or may withdraw from the project without any disadvantage of any kind;

5. There is no anticipated risk to my child;

6. There is no reward, payment or incentive for my child to participate;

7. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my child's anonymity.

I agree for my child to take part in this project.

....
(Signature of parent/guardian) (Date)

....
(Name of child)

This study has been approved by the University of Otago Human Ethics Committee.. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

APPENDIX G2

Discourses of Rural Primary School Science
INFORMATION SHEET FOR STUDENTS

Please read this information sheet before deciding if you want to be a part of this study. If you want to be part of this, thank you. If you do not to take part that is fine and thank you for thinking about being part of my study.

What is this study looking for?

I want your ideas on what you think about science and your abilities in science. There has been a lot of talk about the need for more science in schools. But no one is really asking the students what they think. This study wants to answer the question, "How do students see science and their ability in science?"

Who do I want to talk to about science?

I want to talk to all the boys and girls from XXXX Primary School. I will need to ask your parents or caregivers to give their consent for you taking part.

What will you be asked to do?

Should you (and your parents/caregivers) agree to be part in this study, you will video-taped as you do some science tasks with your classmates at school. This study wants to see how students do science at school.

You will fill in survey about your interest in science. Mrs Penrice will read the questions and you will circle the appropriate face. If there is any writing to do, Mrs Penrice will be there to help you.

You will also be asked to join in some group talks with other students. These group talks should not take more than an hour. These talks will take place in school time on school grounds. This study wants to hear how students see science and what you think about science.

Group talks will be start by asking you:

- What do you think about science?
- Why do we learn about science at school?
- Can you tell me about what you have done in science?
- What would you say you are good at doing in science?

Can I stop?

You may stop being part of the study at any time and that is okay.

What will Mrs Penrice take away from the talks?

These group talks will be video-taped. Anything you say may be used in write-ups about this study. But your name and your school's name will not be used. No one will look to the DVDs unless the published material is challenged. Should this happen, your name and school will not be revealed.

This study wants to ask you questions about science and your experiences in a science programme. The questions that get asked will depend on what the group wants to talk about. If you are unhappy or do not like the questions that get asked, you may stop taking part at any time and go back to class.

Once the session has been transcribed (meaning someone will type up every word that gets said), only Mrs Penrice will have access to the sessions. It will be the transcripts that get used for possible publication. The videos will never be used for public viewing by anyone for any reason.. Every attempt will be made to keep your name and your school's name secret.. You are most welcome to request a copy of the results of the project.

The videos and transcripts will be put into a locked cabinet in a locked office.. At the end of the project any personal information will be destroyed immediately except the DVDs. These are required by the University's research policy to be retained in secure storage for five years, and then these will also be destroyed.

What if you have any Questions?

If you have any questions about this project, please call me:-

Mrs Penrice, XXXXX School, telephone: XXXX

Dr Steven S. Sexton, College of Education, telephone: 03 479 4285

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

APPENDIX G3

Discourses of Rural Primary School Science

CONSENT FORM FOR STUDENTS

I have been told about this study and understand what it is about. All my questions have been answered in a way that makes sense.

I know that:

1. Participation in this study is voluntary, which means that I do not have to take part if I don't want to and nothing will happen to me. I can also stop taking part at any time and don't have to give a reason.

2. Anytime I want to stop, that's okay.

3. Mrs Penrice will video-tape me so that she can remember what I say, but the tape will be destroyed after the study has ended.

4. If I don't want to answer some of the questions, that's fine.

5. If I have any worries or if I have any other questions, then I can talk about these with Mrs Penrice.

6. The paper and computer file with my answers will only be seen by Mrs Penrice and the people she is working with. They will keep whatever I say private.

7. Mrs Penrice will write up the results from this study for her University work. The results may also be written up in journals and talked about at conferences. My name will not be on anything Mrs Penrice writes up about this study.

I agree to take part in the study.

....
Signed Date

APPENDIX H: Assessment Rubric for Scientific Language

Student Name ____Year Level____________

	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	Explores new vocabulary and uses it to label observable features	Experiments with vocabulary and uses correct labels to describe experiences	Develops and uses scientific terms and symbols Recognises that some words have special scientific meanings	Uses a range of scientific terms and symbols appropriately Correctly distinguishes between scientific and everyday meaning for terms used	Uses a range of scientific terms and symbols appropriately with increasing reference to abstract ideas
Evidence					